BBC

EUROPE'S ASTEROID MISSION TO DEFEND EARTH

The plan to redirect the orbit of a near-Earth object

#182 JULY 2020

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

SEE IT THIS MONTH

GIANTS OF THE SKY

JUPITER

SATURN

Don't miss Saturn and Jupiter, the Solar System's largest planets, together at their brightest

SATURN'S STUNNING RINGS

Discover the spectacular sight this month

ENHANCED VISION

We test the Unistellar EVscope's live electronic views for detail

THE MOON OF FIRE

Jupiter's volcanic moon Io reveals its fiery secrets

SINGULAR SATELLITE

The unique genesis of Saturn's moon Titan

SUN SPECTACULAR

How to take award winning solar images

EXOPLANET EXTENSION

TESS mission renews its search for alien worlds


COURAGE IS NOT BEING FEARLESS - CONISTON - MARLOE WATCH COMPANY - DESIGNED IN BRITAIN
"Each one is a miniature world unto itself, a tiny functioning mechanism, a congeries of minute and mysterious moving parts. Moving parts! And consequently these watches are, in a sense, alive. They have heartbeats".
William Gibson on mechanical watches
BEYOND EXPECTATION
WWW.MARLOEWATCHCOMPANY.COM
MARLOE
WATCH COMPANY

Welcome

Enjoy the gas giants, Jupiter and Saturn, at opposition

Later this month stargazers are in for a treat, when two giants of the night sky, Saturn and Jupiter, both reach opposition within a week of each other. Around this time they'll be close together, and at their highest and brightest in the sky. We've got all the essential details you need to make the most of this wonderful summer evening view in the Sky Guide from page 39; it's a foretaste of December's Great Conjunction, when these two gas giant planets will appear as one bright star to the naked eye.

Train a telescope on these worlds and you'll reveal even more wonders: Saturn its majestic rings, and Jupiter its retinue of moons. Jenny Winder's article on page 64 will really enrich your observations of the former, while Will Gater's feature on page 26 will bring you up to date with the latest science from one of Jupiter's most fascinating satelllites, the fiery Io.

Shortly after this issue goes on sale we also mark Asteroid Day (30 June), and on page 56 you'll find a special report from Sean Blair on the European Space Agency's Hera mission, part of a joint endeavour with NASA to alter the orbit of an asteroid deep in space.

Don't forget that our special subscription offer is still running. You can have your next three issues delivered to your door, without starting a Direct Debit, and still save on the price. If you're happy to set up a Direct Debit you'll make even more savings, and your first six issues will be just £9.99. Pick what works for you at **www.buysubscriptions.com/SKspring3** or call us on **03330 162 119** and quote the code '**SPR3MPG, *BBC Sky at Night Magazine***'. See page 89 for more details.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Thursday 16 July.

HOW TO CONTACT US

Subscriptions, binders and back issues
03330 162119*
Mon–Fri 8am–6pm; Sat 9am–1pm

*Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. If calling from overseas, please dial +44 (0)1604 973727

Editorial enquiries
+44 (0)117 300 8754
9.30am–5.30pm, Mon–Fri

Advertising enquiries
+44 (0)117 300 8145

Print subscription enquiries
bbcskyatnight@buysubscriptions.com

Digital subscription enquiries
bbcskyatnightdigital@buysubscriptions.com

Editorial enquiries
contactus@skyatnightmagazine.com

Subscription enquiries
UK enquiries: FREEPOST IMMEDIATE MEDIA (please write in capitals)
Overseas enquiries: PO Box 3320, 3 Queensbridge, Northampton NN4 7BF, UK

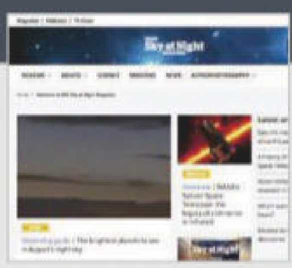
Editorial enquiries
BBC Sky at Night Magazine, Immediate Media Co Bristol Ltd, Eagle House, Colston Avenue, Bristol BS1 4ST

Become an Insider

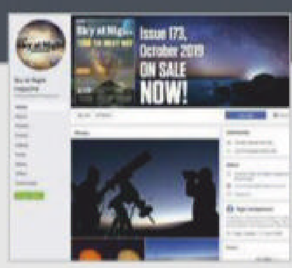
The more we know about what you like, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel 'Insiders'. Just log on to **www.immediateinsiders.com/register** to fill out the short registration survey and we'll be in touch from time to time to ask for your opinions on the magazine and other relevant issues.

Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 16



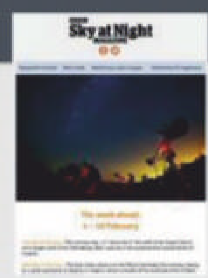
Online
Visit our website for competitions, astrophoto galleries, observing guides and more



Social Media
Follow us on Twitter, Facebook, and Instagram for space news, astro images and website updates

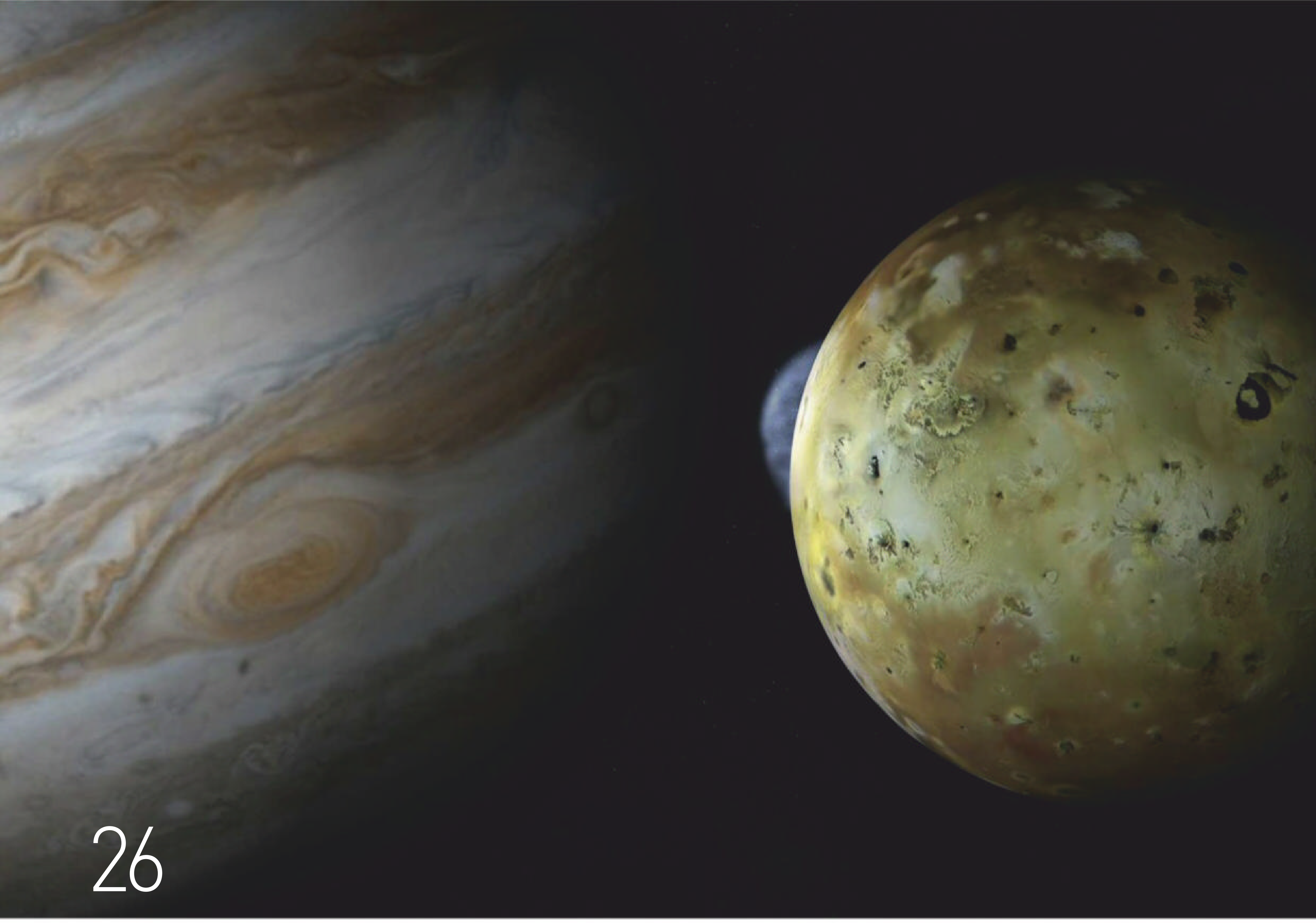
Podcasts
Listen to our Radio Astronomy podcasts where the magazine team and guests discuss astro news

Tablet/phone
Get each month's issue on your Apple or Android device, now with bonus image galleries



eNewsletter
The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com



CONTENTS

(C) = on the cover

Features

Regulars

Astrophotography

Reviews

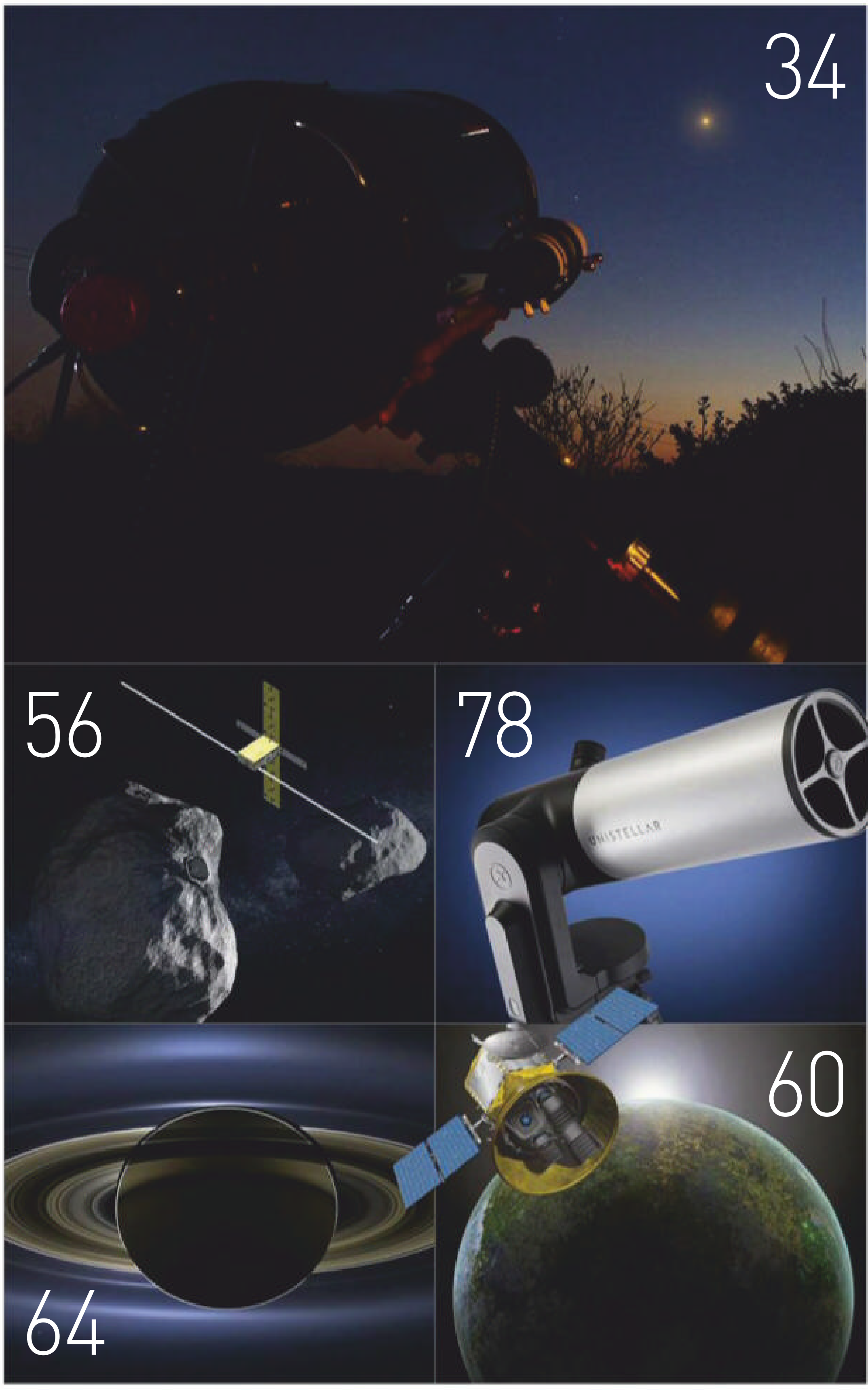
16-PAGE STARGAZING GUIDE

The Sky Guide

COVER MAIN IMAGE: BLACKBECK/ISTOCK/GETTY IMAGES. THIS PAGE: IANM35/ISTOCK/GETTY IMAGES, PETE LAWRENCE, ESA/GOMSPACE, @THESHED_PHOTOSTUDIO, NASA/JPL-CALTECH/SSI, JAMESMCQ24/ISTOCK/GETTY IMAGES, BBC X 3

New to astronomy?

To get started, check out our guides and glossary at **www.skyatnightmagazine.com/astronomy-for-beginners**



This month's contributors

Will Gater

Astronomy journalist

"This was a fascinating story to write. Io's dynamism is just amazing and the possibility we might see a mission to study it in the coming years is really exciting. **Will takes an in depth look at Io, Jupiter's moon.** page 26

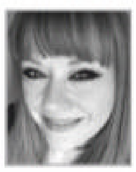
Pete Lawrence

***Sky at Night* presenter**

"Mars fever is starting to take hold as the planet improves in both position and appearance ahead of a very favourable opposition in October". **Pete provides top tips for observing the Red Planet.** page 32

Mary McIntyre

Outreach astronomer



"This was a really fun project. It's amazing what you can make with very basic ingredients and I learned so much about Eros." **Mary enjoys making a realistic model of a near-Earth asteroid.** page 66

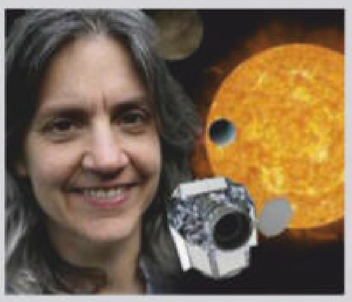
Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/69MHCFS/** to access this month's selection of exclusive Bonus Content.

JULY HIGHLIGHTS

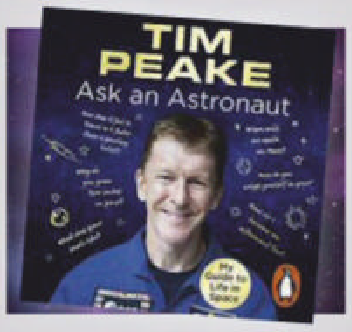
Watch May's *The Sky at Night*

Filming in lockdown, Maggie, Chris and Pete show how astronomy can help in these challenging times.



Interview: ESA's new exoplanet mission

Project scientist Kate Isaak reveals how the new European CHEOPS mission will study planets orbiting distant stars.

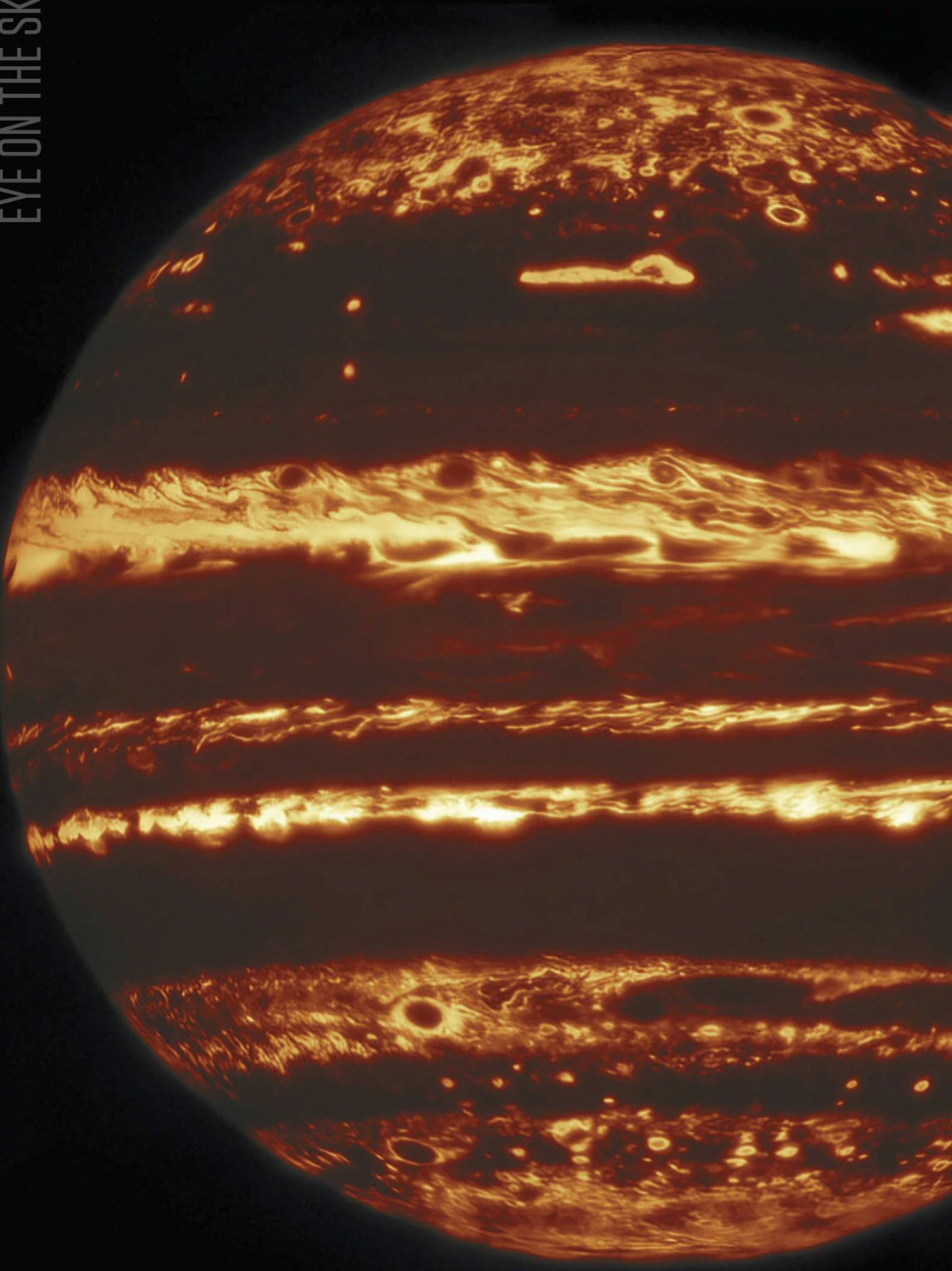


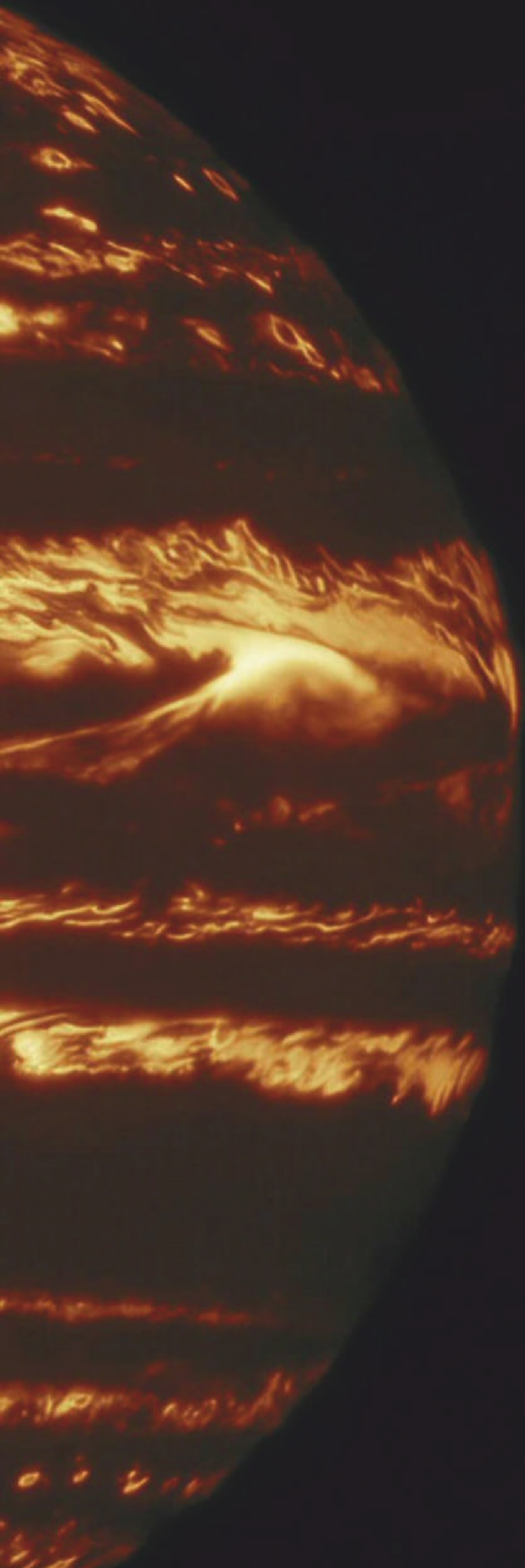
Audiobook preview: Ask An Astronaut

British astronaut Tim Peake answers some of the questions put to him by the public in this audiobook extract.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.





JUPITER ALIGHT

Lucky imaging reveals an ultra-sharp image of our largest planet

GEMINI NORTH TELESCOPE, 7 MAY 2020

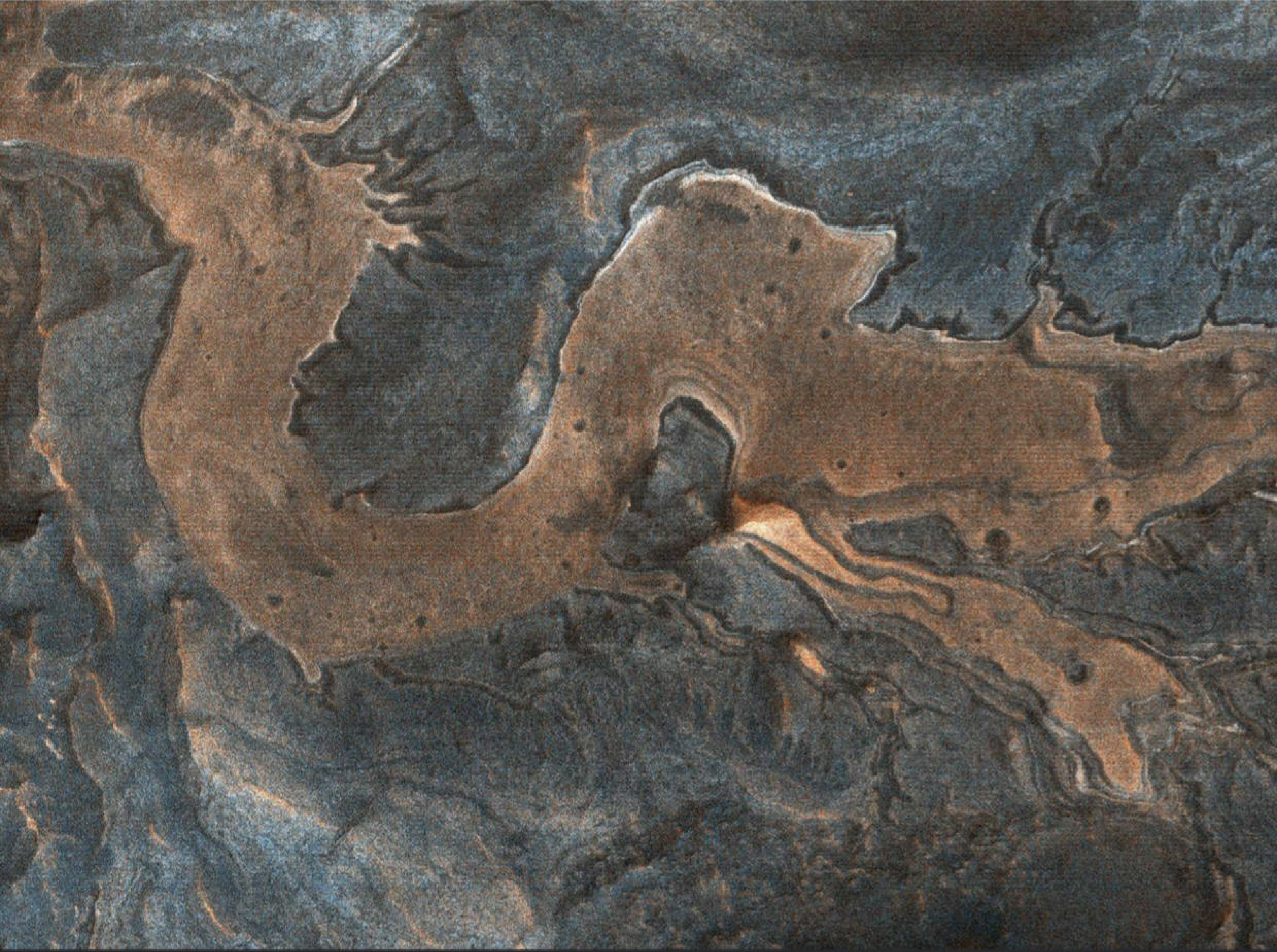
When it reaches opposition in the middle of this month, we can expect to get our best views of Jupiter for the year – but nothing like this.

One of the highest resolution pictures of the planet ever taken from Earth, it was captured by the Gemini North 8.1m diameter infrared telescope at Hawaii's Mauna Kea. Researchers used 'lucky imaging', assembling the picture from hundreds of very short-exposure shots, with only the sharpest portions – where the blur of Earth's atmosphere was minimal – selected to build a global mosaic.

Infrared light can pass through Jupiter's clouds to reveal the deeper layers of its atmosphere. Alongside Hubble's optical observations and radio data from the Juno spacecraft, the observatory is helping to reveal the secrets of our Solar System's largest planet as never before.

MORE ONLINE
A gallery of these and more stunning space images

INTERNATIONAL GEMINI OBSERVATORY/NOIRLAB/NSF/AURA MH WONG (UC BERKELEY) AND TEAM



△ Red Planet dragon

MARS RECONNAISSANCE ORBITER, 11 APRIL 2020

There's a little piece of Welsh heritage on Mars, judging by this dragon emblazoned on the Red Planet. Wind-whipped deposits and the action of water are thought to have caused the beastly shape that meanders across the southwestern Melas Chasma, part of the colossal Valles Marineris canyon system at the planet's equator.

Dance partners ▷

ESO, 18 MAY 2020

The two performers in this European Southern Observatory image may be heading towards a collision, or perhaps swinging away from each other on the galactic dancefloor. Spiral galaxies NGC 5426 and NGC 5427, together known as Arp 271, have for millions of years danced around one another, their gravitational interaction evidenced by wisps of dust and young stars strung between them.

NASA/JPL/UARIZONA, ESO, THE PLANETARY SOCIETY, X-RAY: NASA/CXC/SAO/V.PAREKH, ET AL. & ESA/XMM-NEWTON; RADIO: NCRA/GMRT

Setting sail ▷

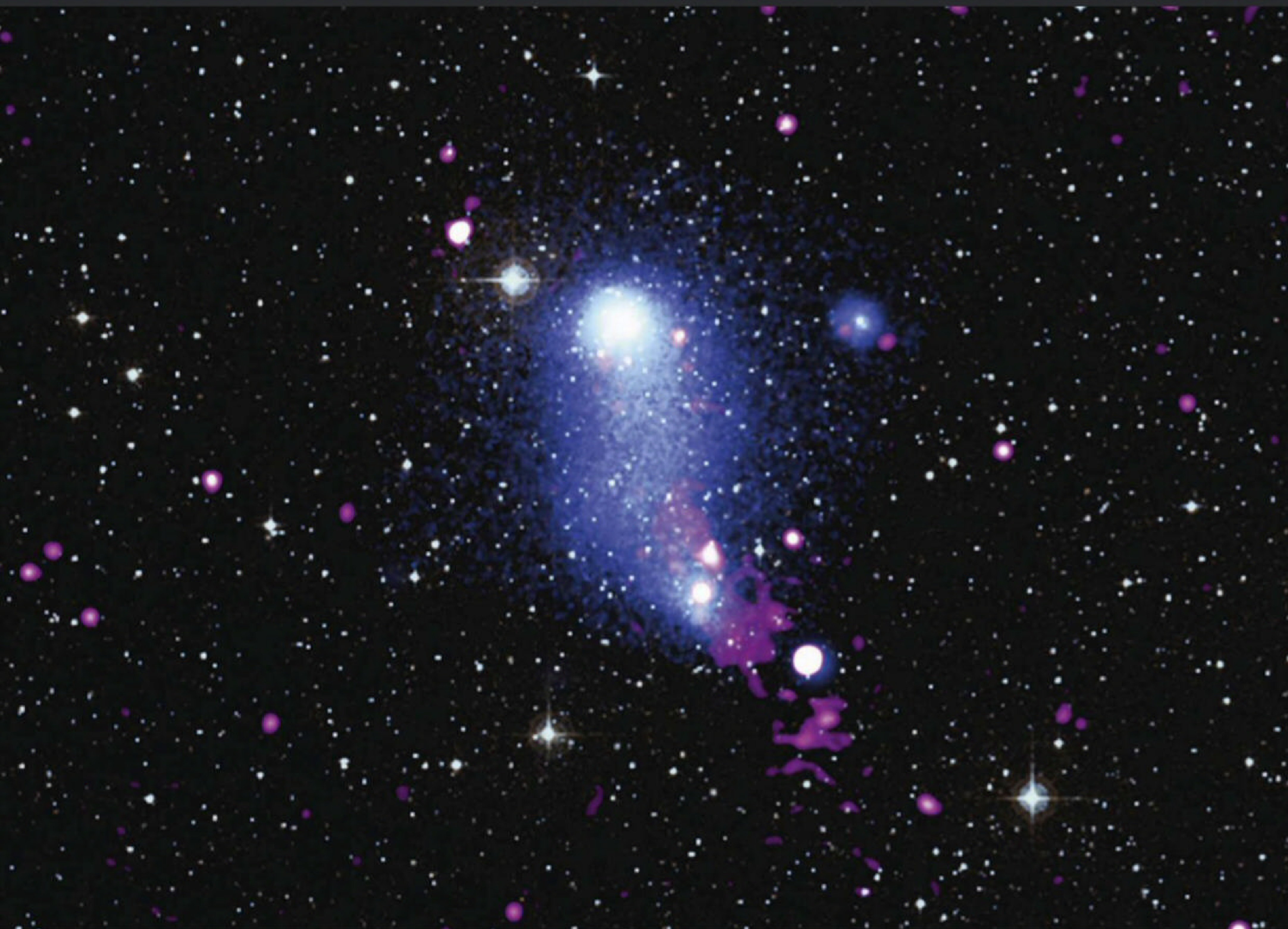
LIGHTSAIL 2, 9 FEBRUARY 2020

The Red Sea and the Nile pass below LightSail 2, the Planetary Society's crowdfunded spacecraft launched in June 2019 and the first in Earth orbit propelled solely by sunlight. Using a large, aluminised sail the size of a boxing ring, it aims to demonstrate solar sailing as a means of propulsion for CubeSats. Its mission will end in a fiery reentry to Earth's atmosphere this month.

▽ Building bridges

CHANDRA X-RAY OBSERVATORY, XMM-NEWTON, GIANT METREWAVE RADIO TELESCOPE, 11 MAY 2020

A bright, superheated arch of gas spans the distance between two vast galaxy clusters in this composite optical, X-ray and radio image. The 'bridge' of Abell 2384, 1.2 billion lightyears from Earth, is an unusual remnant of a past collision between the two clusters. Over 3 million lightyears wide and with a mass of 6 trillion Suns, it appears to bend as the result of jets shooting out from a supermassive black hole at the heart of the southern galaxy cluster.



The latest astronomy and space news, written by Elizabeth Pearson

BULLETIN

By tracking its two companion stars, ESO scientists have revealed a black hole in the system HR 6819

Nearest stellar-mass black hole revealed

Giving off no radiation, it was only discovered by its gravitational effects

Astronomers have discovered a black hole just 1,000 lightyears from Earth, making it the closest black hole known to date. It's the first stellar-mass black hole observed which isn't interacting with its environment, making it truly black.

All other black holes we know of in our Galaxy cause great disturbances in the surrounding gas, which then emit bright radiation, revealing the otherwise invisible objects to astronomers. However, this black hole has no such bright emission, and was only discovered as gravitationally bound to two stars in the system HR6819, one of which looks as if it's being pulled on by an unseen companion.

"An invisible object with a mass at least four times that of the Sun can only be a black hole," says Thomas Rivinius from the European Southern Observatory (ESO), who led the study. "There must be hundreds of millions of black holes out there, but we know about only very few. Knowing what to look for should put us in a better position to find them."

The black hole, or at least its home system, is bright enough to be seen in the Southern Hemisphere constellation of Telescopium using just the naked-eye, meaning that astronomers around the world could soon be casting their gaze towards our newly discovered neighbour.

"We were totally surprised when we realised that this is the first stellar system with a black hole that can be seen with the unaided eye," says Petr Hadrava from the Academy of Sciences of the Czech Republic in Prague. **www.eso.org**

Comment
by Chris Lintott

When I spoke to Thomas Rivinius I was fascinated by the accidental nature of the discovery. The team didn't set out to find a black hole, but were interested in the properties of this unusual system. One of the two 'normal' stars spins quickly, the other slowly, an odd combination for a stellar system where they must have evolved together.

Although ESO's discovery had made headlines, Thomas explained with regret that they still hadn't answered their original question. The black hole adds a further mystery – such objects are supposed to form in supernovae; how can a system bound by gravity survive such an event without being ripped apart? HR6819 will keep us guessing.

Chris Lintott co-presents *The Sky at Night*

Death of the dinosaurs: artwork depicts the moment the asteroid struck in present-day Mexico

Dinosaurs doomed by steep asteroid

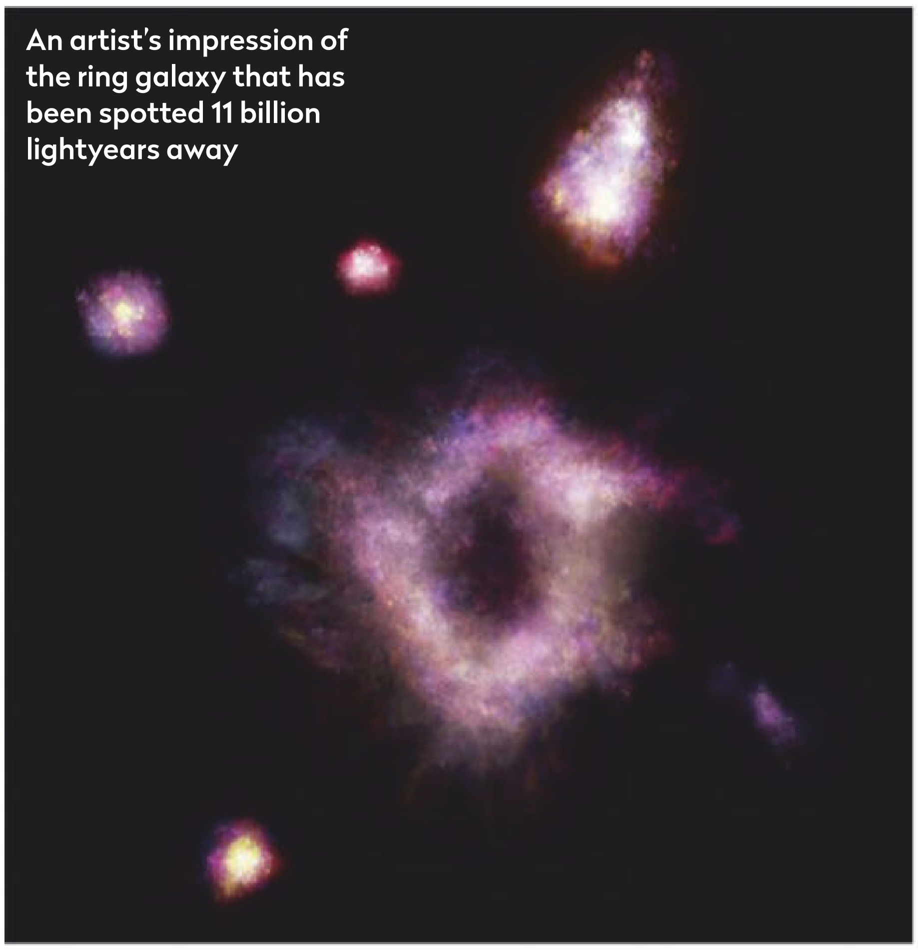
The killer space rock hit at its most destructive angle

The asteroid which killed the dinosaurs struck Earth at the deadliest angle possible, according to a recent set of simulations.

Around 66 million years ago, a giant meteor impacted Earth releasing vast amounts of carbon dioxide, water and sulphur into the atmosphere, creating a nuclear winter and killing off 75 per cent of all life on Earth, including the dinosaurs. By combining geological data from the resulting Chicxulub crater and simulations of the strike, planetary scientists have determined the asteroid came in towards Earth at a steep angle, around 60°.

"We know that this was among the worst case scenarios for the lethality on impact, because it put more hazardous debris into the upper atmosphere and scattered it everywhere – the very thing that led to a nuclear winter," says Gareth Collins, from Imperial College London, who led the study. **www.imperial.ac.uk**

Earliest ring galaxy revealed



An artist's impression of the ring galaxy that has been spotted 11 billion lightyears away

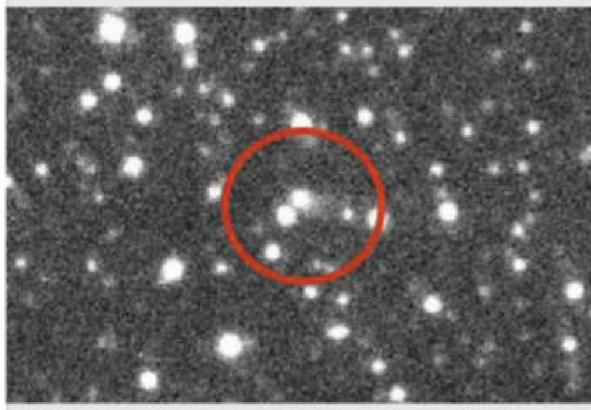
The Universe's oldest doughnut – otherwise known as a ring galaxy – has recently been spotted 11 billion lightyears away. It's the first time such a ring has been spotted in the early Universe.

"It is making stars at a rate 50 times greater than the Milky Way," says Dr Tiantian Yuan from Australia's ARC Centre for Excellence, who led the study. "Most of that activity is taking place on its ring – it truly is a ring of fire."

The ring is thought to have been formed by a collision of two galaxies. For this to be the case, one of the galaxies must have formed its thin disc – the plane which holds most of a spiral's stars – much earlier than expected.

"[With] this ring galaxy, we are looking back into the early Universe by 11 billion years, to a time when thin discs were only just assembling. For comparison, the thin disc of our Milky Way began to come together only about nine billion years ago," says Kenneth Freeman from the Australian National University. **https://astro3d.org.au/**

NEWS IN BRIEF



Asteroid with a tail found

An asteroid with a comet-like tail has been spotted near the orbit of Jupiter by the ATLAS Telescope. It's thought the space rock contains water ice, which was recently disturbed to produce the tail. It is one of a growing number of crossover objects, bridging the gap between asteroids and comets.

Telescope renamed after NASA pioneer

Infrared telescope WFIRST has been renamed in honour of Nancy Grace Roman, NASA's first chief astronomer, who died in 2018. Known as the 'mother' of the Hubble Space Telescope, Roman spent much of her career advocating for new tools to allow astronomers to explore the Universe.

Nearest exoplanet confirmed

The presence of a planet around our nearest star, Proxima b, has been independently verified by the European Southern Observatory's ESPRESSO instrument. The observations found the planet is around 1.2 times the mass of the Earth and orbits every 11.2 days.

Making history: after a flawless launch of Crew Dragon on 30 May, Doug Hurley and Rob Behnken (inset, top) gave viewers a guided tour of their spacecraft, before joining the crew on the ISS (inset, below)

Crew Dragon launch a success

The mission is the first time a private company has launched humans into space

The first ever commercially produced crew vehicle, SpaceX's Crew Dragon module, launched from the Kennedy Space Center on 30 May, docking with the International Space Station 19 hours later. The flight is part of the Demo-2 mission – a final test of the new crew vehicle which will transport astronauts to and from the ISS.

The launch took off at 19:22 UT from Launch Complex 39A – the same launch pad from which NASA sent the Apollo astronauts to the Moon. At the helm were astronauts Doug Hurley and Robert Behnken, both of whom have two Shuttle flights to the ISS under their belts.

"While it was an exciting ride, I think we got a couple of minor surprises, just in terms of the way the vehicle is moving and shaking," Behnken said after arriving at the ISS.

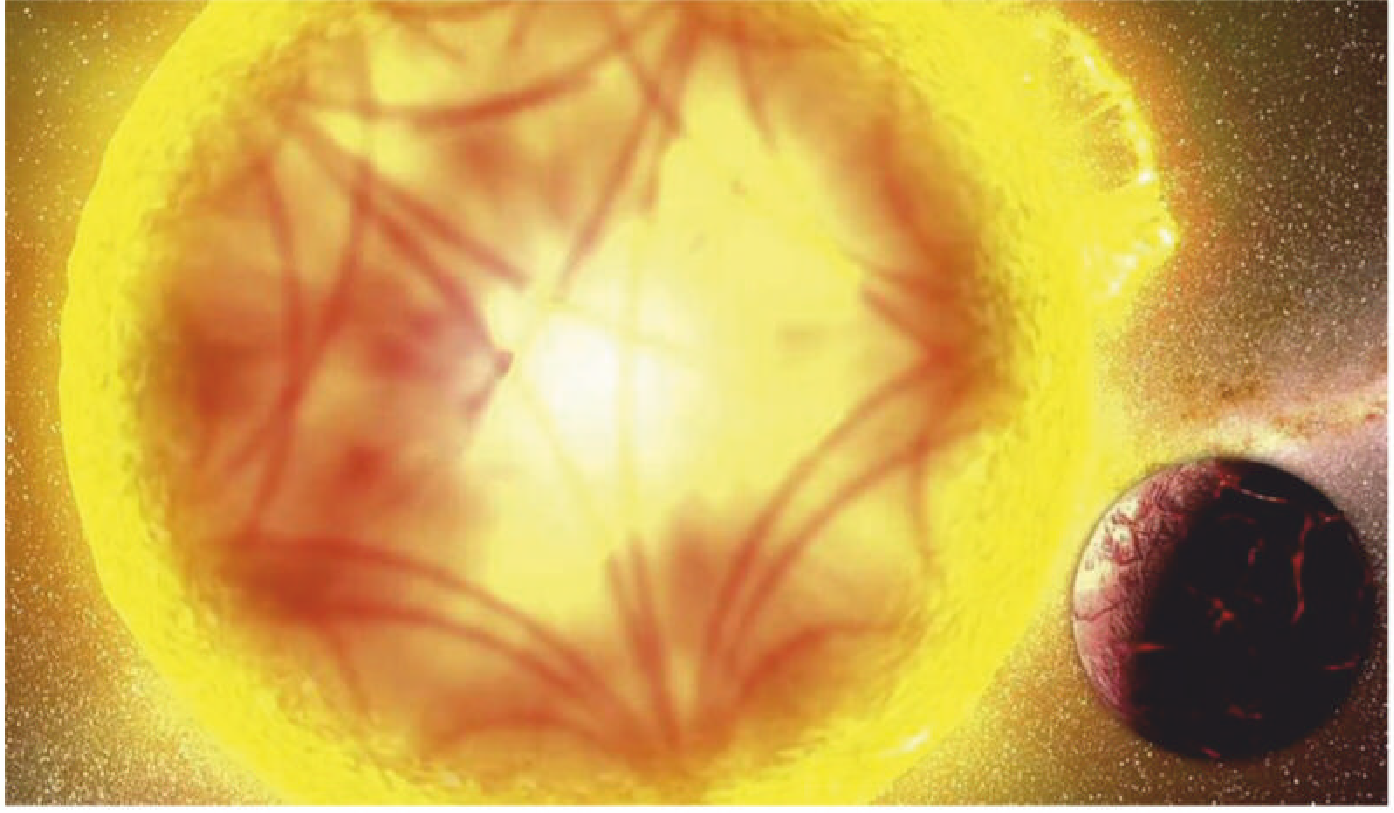
The pair will now become part of the Expedition 63 crew, helping to conduct experiments and maintain the station. The exact length of their stay is still to be determined but it could be as long as 110 days. If the return journey goes well, then the module could begin carrying astronauts to the ISS full-time as soon as 30 August.

The mission is the culmination of NASA's Commercial Crew Program, an initiative which began back in 2010 in response to the cancellation of the Space Shuttle programme. Without the Shuttles the US was unable to launch humans into space themselves and instead had to rely on the Russian Soyuz capsules to reach the ISS.

Rather than developing the module themselves, NASA decided to support private US space enterprise and contracted SpaceX and Boeing to build crew modules capable of carrying up to seven astronauts to low-Earth orbit.

"It's difficult to put into words how proud I am of the people who got us here today," says Kathryn Lueders, NASA's Commercial Crew Program manager. "When I think about all the challenges overcome – from design and testing, to paper reviews, to working from home during the pandemic and balancing family demands with this critical mission – I am simply amazed at what the NASA and SpaceX teams have accomplished together. This is just the beginning." **www.nasa.gov**

SPACE X/NASA X 3, GABRIEL PEREZ DIAZ/INSTITUTO DE ASTROFISICA DE CANARIAS, NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA, NASA/GODDARD/UNIVERSITY OF ARIZONA



▲ An artist's impression of how a few individual waves could travel through a star with a planet in orbit

Taking a reluctant star's heartbeat

The pulse was taken with a telescope designed to find exoplanets

Astronomers have finally heard the heartbeat of a mysterious class of variable star which previously defied having its pulse taken, it was announced in a recent paper.

Scientists used the precise stellar brightness measurements of NASA's Transiting Exoplanet Survey Satellite (TESS) to look at the subtle vibrations of stars. They can use these fluctuations to reveal information about the stars' inner layers, a technique known as asteroseismology. This study focused on 1,000 Delta Scuti stars – bright objects with masses between 1.5 and 2.5 times that of the Sun. However, their rapid spin distorts their shape and muddles the seismic pattern on the surface.

"To use a musical analogy, many stars pulsate along simple chords, but Delta Scuti stars are complex, with notes that seem to be jumbled," says Tim Bedding from the University of Sydney, who led the study. "It was a mess, like listening to a cat walking on a piano."

The precise TESS data allowed the researchers to cut through the noise and identify clear signals for 60 stars. **www.nasa.gov/tess-transiting-exoplanet-survey-satellite**

▸ **To learn more about TESS turn to page 60**

Mud made Mars's landscape

Dishing the dirt: simulations on Martian mud reveal it behaves in a similar way to lava on Earth

Mud once flowed across the Martian surface like lava, according to a novel set of laboratory experiments.

Planetary scientists have long suspected that 'mud volcanoes' played an important role in shaping the landscape of early Mars but knew little about how such mud would act under the low pressure and frigid temperatures found on the Red Planet. To find out, a team of scientists simulated Martian conditions in a laboratory and discovered that mud on Mars acts similarly to lava from the large volcanoes on Hawaii and Iceland.

"Once again, it turns out that different physical conditions must always be taken into account when looking at apparently simple surface features on other planets. We know that we need to consider both mud and lava when analysing certain flow phenomena," says Ernst Hauber from the DLR Institute of Planetary Research in Germany. **www.dlr.de**

NEWS IN BRIEF

Date with an asteroid

NASA's asteroid investigator, OSIRIS-REx, will take its first run at grabbing a sample from asteroid Bennu on 20 October (as illustrated above), after a practice run in August. Once collected, both spacecraft and sample will depart for Earth in mid-2021, arriving back in September 2023.

UK funds space debris research

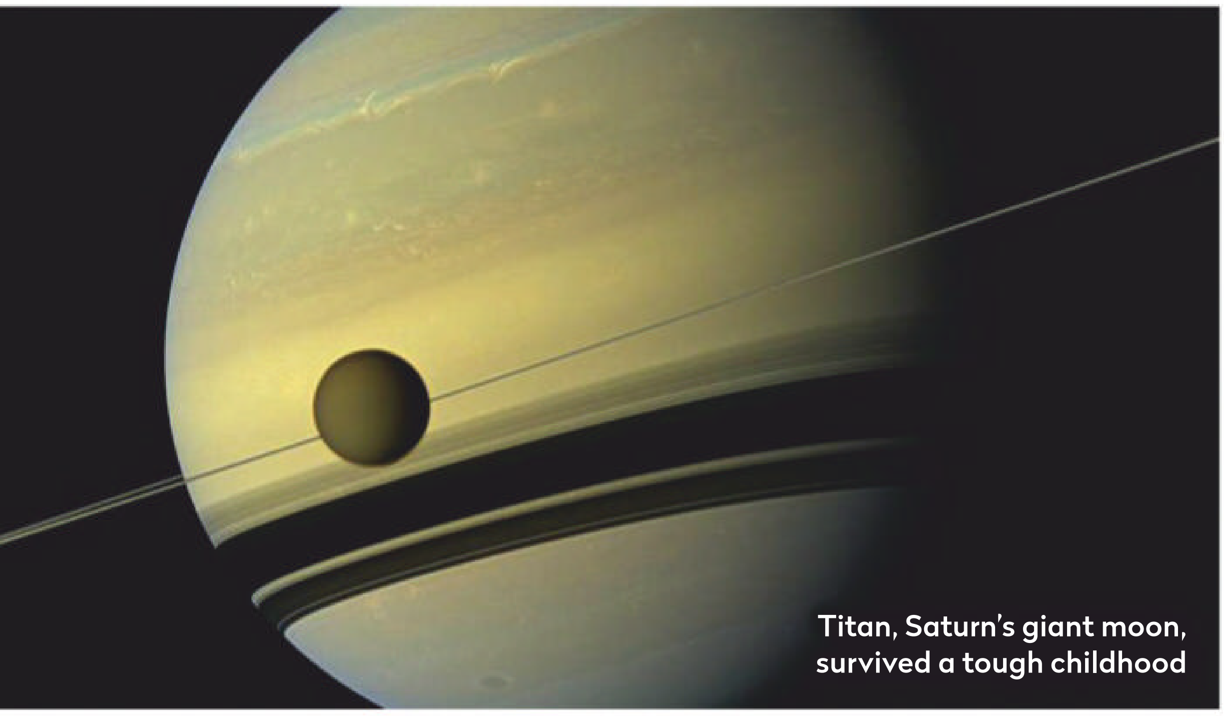
The UK Space Agency has provided £1 million of funding for organisations developing innovative ways to remove space junk from orbit. "Space debris is a global problem and this funding will enable UK companies to develop new methods to help tackle the issue," says Alice Bunn, the agency's International Director.

Observatories reopen

Telescopes on Mauna Kea in Hawaii were given permission to reopen on 9 May. Like many other observatories around the world, they were forced to close in response to the COVID-19 pandemic. Many have resumed observations, keeping staff to a minimum.

Our experts examine the hottest new research

CUTTING EDGE



Titan, Saturn's giant moon, survived a tough childhood

Saturn's moon Titan is perfectly placed

A safe spot in orbit prevented the mammoth moon from being swallowed whole

As gas giant planets in our Solar System, Jupiter and Saturn are pretty similar to each other. They have similar compositions and are both several hundred times more massive than Earth, and so very much in a class of their own even compared to the ice giants Uranus and Neptune.

When it comes to their moons, however, the Jupiter and Saturn systems are wildly different from each other. While both planets have a family of around 80 moons overall, the mass distribution is very different. Jupiter has the four large Galilean satellites – Io, Europa, Ganymede and Callisto – all roughly the same size, whereas Saturn has the single giant moon, Titan. As the largest moon in the Solar System, Titan's even bigger than the planet Mercury.

What determines whether a gas giant gets a family of sizeable moons or a single jumbo satellite? Some moons – like Neptune's Triton, or Phoebe around Saturn – are captured objects, but the majority of satellites around the giants are believed to be born in circumplanetary discs. These arise when an infant star is creating a new planetary system from the large disc of gas and dust swirling around it. Embedded within this are smaller whirlpools around the forming gas giant planets – circumplanetary discs.

Large moons coalescing in this dusty skirt of material tend to spiral in towards the planet as they experience drag from their interaction with the surrounding gas and dust: they are at danger of diving all the way down into the gas giant and becoming destroyed. So what seems most likely is that a giant planet ends up with either no large moons, or a system of several large moons, like the Galilean satellites, that were all saved because the circumplanetary disc was dissipated quickly enough after formation. Finishing with just a single large moon, however, seems much more difficult and leads to the question of how Titan formed.

Yuri Fujii and Masahiro Ogihara, at the Department of Physics, Nagoya University, and National Astronomical Observatory of Japan, respectively, think they've found the answer. As the orbital migration of moons depends on key factors like the density and temperature of dust particles in the circumplanetary disc at different distances out from the planet, they've modelled different systems to study what the configuration of moons ends up like as the disc disperses. How many moons survive, of what size, and at what orbital distance from the central planet?

"Finishing with just a single large moon, however, seems much more difficult and leads to the question of how Titan formed"

Saved in a safe patch

Their simulations showed, as had been expected, that large moons like Titan mostly lose orbital energy in the dusty disc and spiral in towards the planet to be devoured. For particular combinations of moon mass and orbital radius, however, the overall balance of forces causes the moon to instead drift slowly outwards, or even hover at the same orbital distance; these are like safe patches, and a single giant moon is able to survive destruction. What appears to have happened with Saturn is that several inner moons may have spiralled all the way in to be destroyed, but Titan formed in an outer orbit and migrated inwards until it settled in one of these safe patches. Once the disc dissipated, any further migration ceased and Titan has stayed put ever since.

▶ **To find out more about Jupiter's moon Io, turn to page 26.**

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Formation of single-moon systems around gas giants* by Yuri I Fujii and Mashahiro Ogihara. **Read it online at https://arxiv.org/abs/2003.05052**

Galaxies form from the inside out

A novel instrument mapping the age of stars is helping to show how galaxies grow

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

Galaxies are funny beasts. They should be simple systems, and yet answering even basic questions about their formation ties astronomers in knots. Sure, their scale is breathtaking – the Milky Way's few hundred million stars are nothing to be sniffed at – but the shapes of galaxies, and the patterns of the star formation that takes place within them, are sculpted almost entirely by gravity. We understand gravity and yet generations of astronomers have struggled to explain what we see.

Part of the problem, of course, is the distance of the galaxies we're trying to study. Trying to understand the behaviour of systems hundreds of millions of lightyears away requires some ingenuity and this month's paper, by Tom Peterken and friends at the University of Nottingham and elsewhere, makes excellent use of a powerful new type of instrument. MaNGA is an IFU (integral field unit) – a camera which provides a spectrum for many points across the image. The idea is that we get a three-dimensional view of the system, as these spectra enable us to tell how gas and stars are moving.

The team are also able to use the spectra to gain insights into the history of star formation in each part of the galaxy. They do have to assume that things don't get too mixed up over the course of billions of years, but if you make the assumption that stars stay roughly where they form, you can use an instrument like MaNGA to chart a galaxy's history.

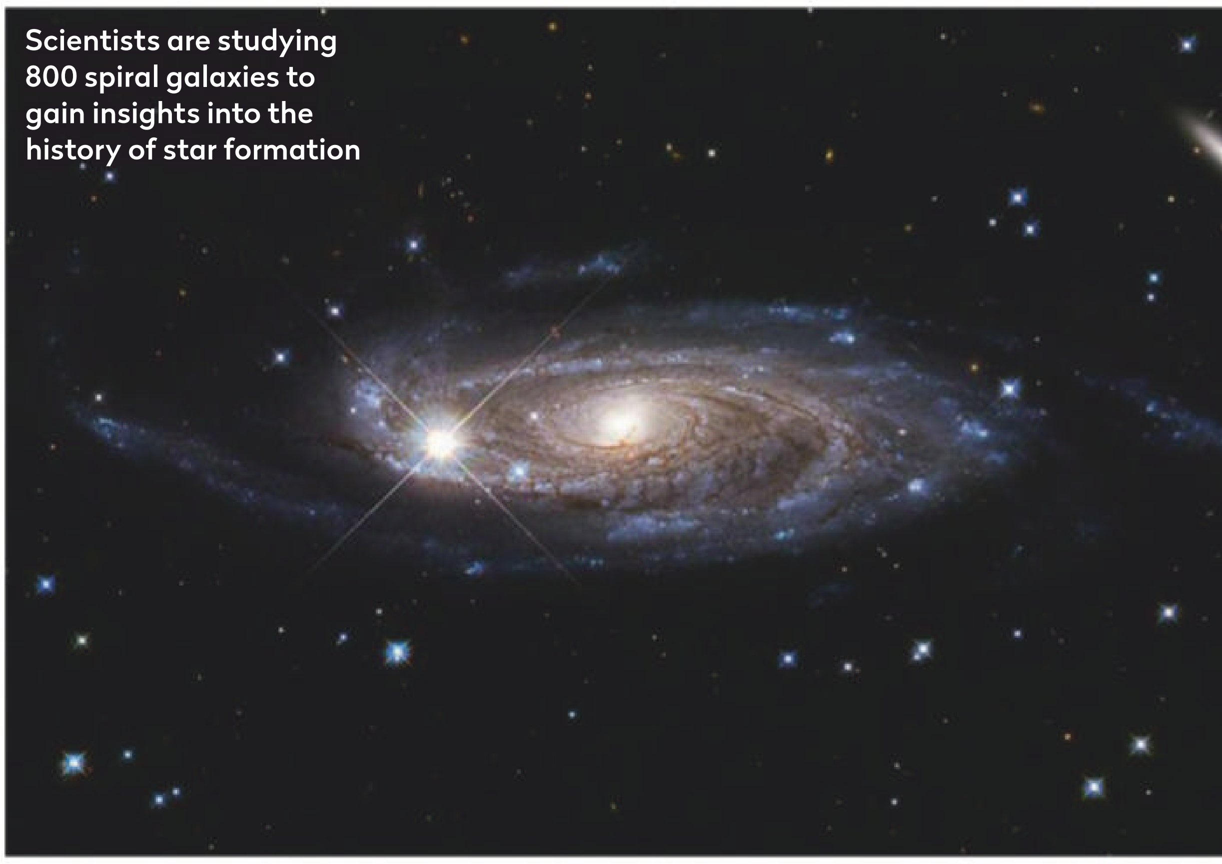
That's what this paper does, focusing on 800 nearby spiral galaxies. Though each individual galaxy is somewhat different, with its own story to tell, they find a remarkable degree of consistency when it comes to stellar age distribution. For these galaxies, the younger stars are spread further than the older stars, which tend to cluster towards the centre of the galaxies. This isn't entirely surprising – many spiral galaxies have a central bulge, which tends to be populated with older stellar populations – but it is shown much more clearly in this careful treatment of the data than it has before.

"Trying to understand the behaviour of systems hundreds of millions of lightyears away requires some ingenuity"

The explanation for this pattern – old stars in the middle and young further out – is that star formation seems to have happened in an 'inside out' fashion, working its way from the denser centre of the galaxy to its outskirts. This is particularly true for the more massive spirals, where perhaps the differences between central and outlying regions are most profound.

Underlying issues

Interestingly, the story told by the star formation histories may not reflect what's going on underneath. If you look only at the stars, then as star formation moves outwards over time galaxies seem to grow, but it turns out the underlying distribution of matter isn't changing at the same rate. If we're too distracted by the sparkling of new stars, we miss the underlying picture. This consistency is also good news for astronomers peering at more distant galaxies, as it suggests that the most massive galaxies we observe, say, from four billion years ago, are still the most massive today. That knowledge should make it easier to follow the course of galactic growth directly, as we continue to tackle the mysteries of these beautiful – and maddening – objects.

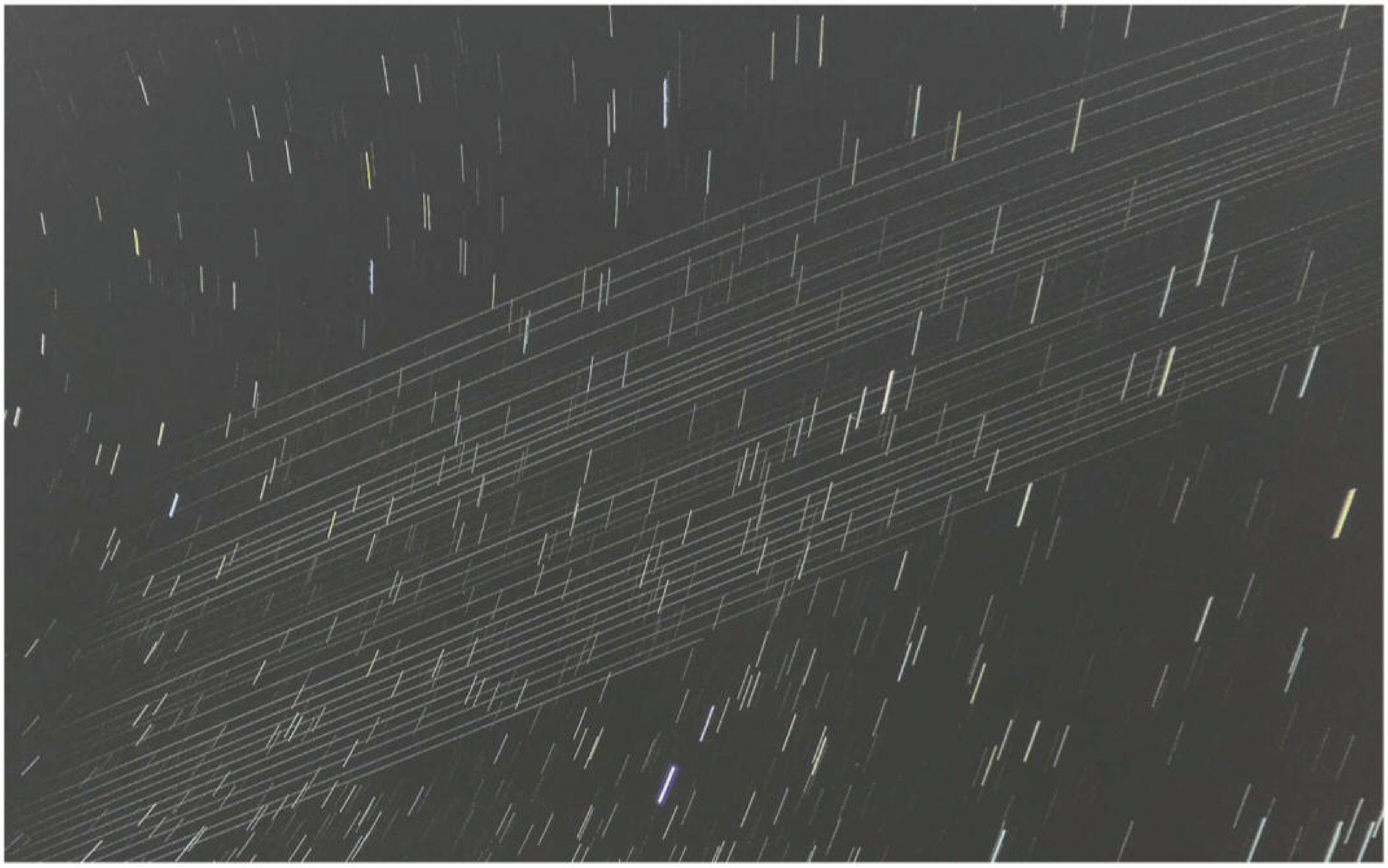


Scientists are studying 800 spiral galaxies to gain insights into the history of star formation

Chris Lintott was reading... *SDSS-IV MaNGA: Excavating the fossil record of stellar populations in spiral galaxies* by Thomas Peterken. **Read it online at: https://arxiv.org/abs/2005.03012**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT



In the latest episode of *The Sky at Night*, professional astronomer **Lucie Green** looked into SpaceX's Starlink project and what the presence of 12,000 satellites could mean for her and fellow scientists

▲ **Train of lights: SpaceX Starlink satellites pass over Córdoba, Argentina on 6 May 2020**

Every project that carries the SpaceX name seems to be an audacious attempt to blaze a trail and leave other companies playing catch up. Elon Musk himself is so prominent when it comes to space exploration that I sometimes wonder when the day will come that I am doing my research using data collected by his spacecraft. But if he wishes to fulfil his dream of creating a human colony on Mars, he needs money.

That's where projects like Starlink come in; a 'megaconstellation' of 12,000 satellites working together to provide a globally accessible internet system. It could open up opportunities for people in hard to reach places, giving them access to knowledge, employment and facilities many of us take for granted – while also making a nice profit for SpaceX. However, our skies are a site of special scientific and cultural interest and these megaconstellations represent a new form of light pollution that could irreversibly change them. With all this in mind, I looked into the Starlink project for this month's episode of *The Sky at Night* to find out what's fact and what's fiction.

The Starlink project kicked off in May 2019 when SpaceX launched 60 prototype satellites to demonstrate that deploying such a large number in one go is feasible. Today over 400 are in orbit.

I went into the film with a healthy dose of scepticism over the mission, but willing to be open minded. Rightly, there has been significant concern voiced across the astronomy community about this project. The satellite 'trains' that I watched passing overhead from the early launches were an astonishing sight and they caused speculation that, in the end, thousands of Starlink satellites would be omnipresent, destroying our views, and the ability to do astrophotography and study large portions of the sky.

Professor Lucie Green is a professor of physics at Mullard Space Science Laboratory and a presenter on *The Sky at Night*

What I learned, though, is that the Starlink project is immensely complex. With engineers probably working under pressure to meet launch deadlines, the issue of light pollution, remarkably, seems to have been overlooked. Authorisation of satellite launches takes place at a national level and there is no legal requirement to factor light pollution into the mission design. This is why it has been so important that we astronomers speak up about the potential impact. It seems that we have been heard.

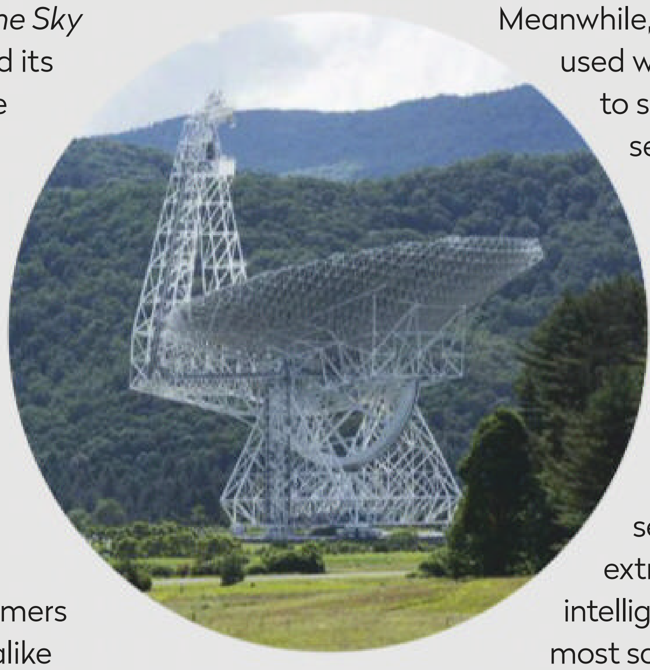
Experimentation with satellite coating and modification to design and orientation have all been tried with some success in reducing the satellites' brightness to just below naked eye visibility once in their final orbit. While this allayed my initial fears, it doesn't solve the significant impact that will be experienced by telescopes carrying out sky surveys, like the Vera Rubin Observatory in Chile, which will scan the sky repeatedly to advance our understanding of dark matter and dark energy.

Starlink is happening and we can't do anything about that, but thank goodness SpaceX is engaging. The lesson I learned is that we have a voice and we can make it heard. So let's use it and not give up stewardship of our night skies to private companies, but keep it for everyone.

Looking back: The Sky at Night

July 1965

On 23 July 1965, *The Sky at Night* celebrated its 100th episode. The team tackled one of humanity's greatest questions: are we alone in the Universe; and if there are civilisations on other planets, how would we contact them?



▲ **The Green Bank radio telescope began the search for alien transmissions**

Though astronomers and philosophers alike had pondered the question for decades, technology only caught up to their musings in the 1960s. Astronomers were then able to listen out for alien radio signals leaking out into space. In 1960, US astronomer Frank Drake began Project Ozma, using the Green Bank radio telescope in West Virginia to listen to nearby stars.

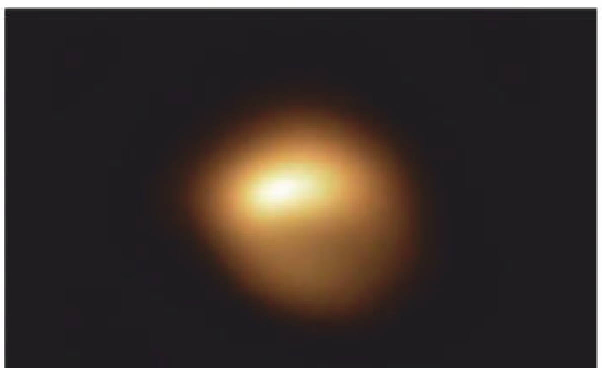
Meanwhile, the Soviet Union used wide-field antennae to search large sections of the sky, hoping to hear a powerful radio signal among the noise.

Since the 1960s there have been many large-scale searches for extra-terrestrial intelligence (SETI). Today, most scientific searches look for chemical signs of biological life – be it on the surface of Mars or in the atmosphere of an exoplanet – but there are still several searches hunting out distant radio signals, such as the privately funded Breakthrough Listen project. Alas, all these projects have been unsuccessful in their search – at least so far.

The lives of stars

This month *The Sky at Night* team look at the lives of stars. Chris investigates why Betelgeuse dimmed in late 2019 and speaks to researchers who've been photographing the star using the Very Large Telescope. Maggie wonders what the discovery of the brightest ever supernova means for our understanding of stars, while Lucie looks closer to home and reveals the science of our own Sun. Pete tries his luck at imaging a new supernova in galaxy M61.

BBC Four, **12 July**, 10pm (first repeat
BBC Four, **16 July**, 7.30pm)
Check www.bbc.co.uk/skyatnight for more up-to-date information



The surface of Betelgeuse, as seen by the VLT in December 2019

Emails – Letters – Tweets – Facebook – Instagram – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's titles

PHILIP'S The 'Message of the Month' writer will receive a bundle of four top titles courtesy of astronomy publisher Philip's: Ian Ridpath and Wil Tirion's *Star Chart*, Robin Scagell's *Guide to the Northern Constellations*, and Heather Couper and Nigel Henbest's *2020 Stargazing* and a planisphere for the night skies at latitude 51.5° north.

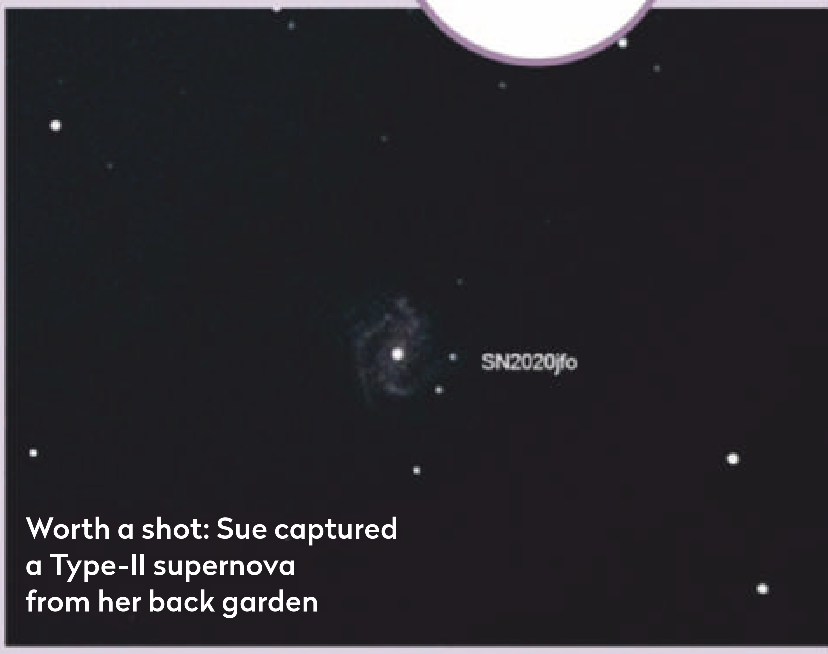
Winner's details will be passed on to Octopus Publishing to fulfil the prize

Supernova snap

Even in these trying times astronomy is still a great spirit lifter. I have been a regular attendee of Chesterfield Astronomical Society for the past 10 years but, of course, the current lockdown restrictions prevent us going to the Observatory. The fact that you can still enjoy astronomy from a back garden anywhere is a real bonus. I have my own telescopes but even if you haven't you can still enjoy the beauty of the night sky. Anyone can take a deckchair outside or even a blanket and just look up; I often still just go out and look up at the night sky.

If you do have a telescope or even binoculars, it opens up the sky to some fascinating objects. After the news of a supernova (SN 2020jfo) in the Virgo Cluster (M61) in mid-May I decided to a try and image it with my Canon EOS 1100D DSLR camera, 6-inch Newtonian and EQ5 mount. I captured 12 frames, stacked them in DeepSkyStacker and processed the image further in GIMP, and am quite pleased with the result. I feel I'm still a novice to this, but it just goes to show what can be achieved from a fairly light-polluted back garden.

Sue Silver, Sheffield



Worth a shot: Sue captured a Type-II supernova from her back garden

Well done Sue, a fantastic record of this event, which observations suggest is a Type II supernova – the final act of a supergiant star whose core collapsed after running out of nuclear fuel. ***– Ed.***

Tweet

Chris Jones
@jonesy1007 • 25 May
Tonight's crescent moon looking stunning at 10% over Shropshire @VirtualAstro @shropastrosoc @BBCStargazing @skyatnightmag #moon #luna #Crescent

Box of delights

One thing about self-isolation is the opportunity it gives to catch up on those jobs you never quite got around to. Over the years I've accumulated a lot of eyepieces and was forever unsure which one was in which box, especially in the dark. My solution has been to make a proper box for them. I've used an off-cut of 5mm plywood, brass fittings, a can of spray paint and an off-cut of 25mm thick foam built up in layers – *et voilà*! The holes in the foam need a bit of cleaning up, but the result is very satisfactory. It also allowed me to sort through all my eyepieces and select the best ones.

Harold Mead, Taunton

The best telescope?

Like every family we have our fair share of squabbles but there is nothing quite so divisive as our preference of telescope. My wife extols the elegance of a good refractor with the mantra, "It's quality not quantity." She believes that nothing can match the crisp views offered by her 4-inch doublet refractor. However, my son of 15 is a lover of large Dobsonians and will retort with, "Aperture is king," or, "Best bang for your buck with a Dob!"

I teeter on rather shaky middle ground, preferring the compromise of an 8-inch Schmidt-Cassegrain: "The best of both worlds, with decent aperture, sharp views and easy portability." To which my wife or son will often flatly reply with the remark, "Ah yes, the jack of all trades, but the master of none."

I am glad to say that there is one thing we do all agree on, and that is our fondness of *BBC Sky at Night Magazine*. Each month when the postman brightens our door with the latest issue, there follows a mad dash to the door in a race to catch the first glimpse of the always fascinating content of your splendid publication.

Thankfully, things eventually settle down and raving rants are replaced with reasoned recourse. For this, I thank you very much.

Fionn Daly, Dublin

Very pleased to be able to help restore reason, Fionn, thanks for sharing! ***– Ed.***

Great spot

I spotted this remarkably accurate Great Red Spot on a sphere of sandstone.

Trevor Haddrell, via email

Busy bees

Just a thought… if 75 per cent of all food on Earth is pollinated by bees, then surely ▸

ON FACEBOOK

WE ASKED: What are you most looking forward to for the rest of 2020?

Tony Moss When our local astronomy club can meet up again.

Laurence Blundell The oppositions of Jupiter, Saturn and Mars, and also (hopefully!) visiting some astronomy shows, some of which had to be postponed earlier in the year.

Gary Hendrick Great Conjunction of Jupiter/Saturn on 21st Dec.

Keith Moseley Any decent comet that doesn't disintegrate or hide in the Southern Hemisphere.....or just some noctilucent clouds will do.

David Millar Galloway Star Camp in October.

Ben Head Last night I saw four meteors in the space of 90 mins; three were dim but one was really bright. I can't wait for the Perseids this year – I've found the perfect location to watch.

AR Gavin The launch of the NASA Mars 2020 mission.

Barry Gowans Honestly, I'm looking forward to the freedom of travelling to the local dark-sky site. Anything else (specific) is just a little bonus.

Peter Cooper The astronomical event of NO CLOUDS in the sky, so I can finally see Swan. (Yes, I'm exercising sarcasm: three weeks of cloud cover does that to you)

SCOPE DOCTOR

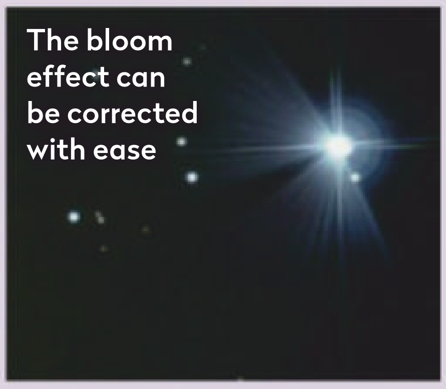
Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to
scopedoctor@skyatnightmagazine.com

I image with a Sky-Watcher 200PDS Newtonian reflector, but my images suffer from a bloom effect. I've recollimated and painted the inside of the tube black to no avail. What else can I try?

DEREK MORTON



The bloom effect can be corrected with ease

The bloom effect is a haziness around bright light sources like stars and there are a couple of potential sources. The first is that the primary mirror may have a turned down edge, where the outer edge of the mirror is incorrectly polished. Sky-Watcher mirrors are pretty good in this regard, so this is the least likely cause. The second and more likely cause is that the mirror clips that hold the primary mirror in place are intruding into the light path and causing a diffraction artefact.

Happily, both faults can be resolved in the same manner. If you make a ring-shaped mask out of black cardboard, which just cuts off the mirror clips from view when fitted over the mirror's edge, it should remove the artefact.

Looking at the diffraction pattern caused by the secondary mirror spider vanes, it's also clear that opposing vanes are not parallel to one another, which is resulting in the formation of double diffraction spikes. This should be corrected by careful adjustment of the external thumb bolts that hold the spider vane within the optical tube.

Steve's top tip

What is a neutral density filter used for?

Neutral density filters are commonly used by photographers to reduce the amount of light reaching the camera's sensor, allowing a wider range of shutter and aperture settings to be selected to obtain special imaging effects. These filters are particularly useful when photographing bright objects like reflections on water. However, this type of filter can also be installed inside the barrel of an eyepiece to reduce the amount of light reaching an observer's retina, making it much more comfortable to view very bright objects like the Moon. Neutral density filters are designed to reduce all wavelengths of light equally.

Steve Richards is a keen astro imager and an astronomy equipment expert

BBC Sky at Night MAGAZINE

IMMEDIATE MEDIA Co

BBC Sky at Night Magazine is published by Immediate Media Company Bristol Limited under licence from BBC Studios, which helps fund new BBC programmes.

EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Neil McKim
News Editor Elizabeth Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Shaoni Bhattacharya, Sean Blair, Lewis Dartnell, Glenn Dawes, Ben Evans, Alan Friedman, Will Gater, Lucie Green, Tim Jardine, Pete Lawrence, Chris Lintott, Mary McIntyre, Chris North, Katrin Raynor-Evans, Steve Richards, Steve Tonkin, Hannah Wakeford, Jane WIlliamson, Jenny Winder

ADVERTISING SALES
Advertising Manager Sam Jones +44 (0)117 300 8145, sam.jones@immediate.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Ad Services Manager Paul Thornton
Ad Coordinator Florence Lott
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
International Partners' Manager Anna Genevier

MARKETING
Head of Circulation Rob Brock
Head of Marketing Jacky Perales-Morris
Marketing Executive Kellie Lane
Press and PR Manager Emma Cooney

PUBLISHING & MANAGEMENT
Publisher Jemima Dixon
Managing Director Andy Healy
Group Managing Director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, Editorial Review Boards Nicholas Brett
Managing Director, Consumer Products and Licensing Stephen Davies
Head of Publishing Mandy Thwaites
Compliance Manager Cameron McEwan
UK Publishing Coordinator Eva Abramik
UK.Publishing@bbc.com; www.bbcstudios.com

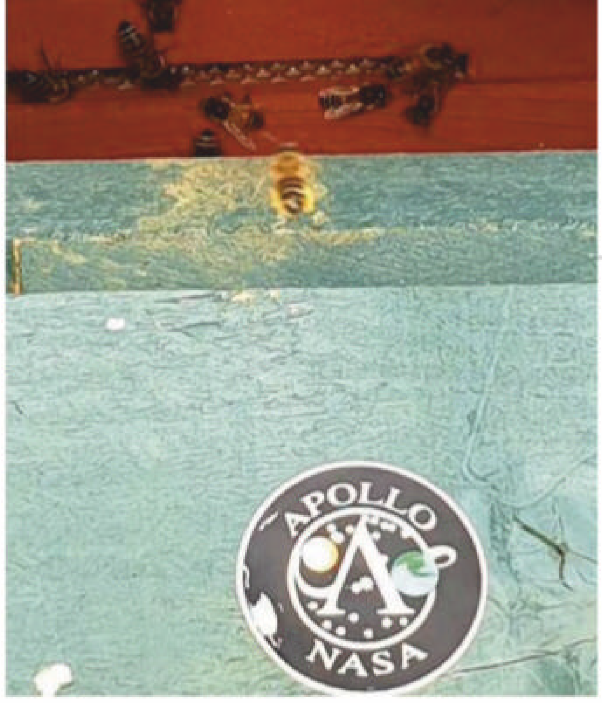
SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

ipso Regulated

We abide by IPSO's rules and regulations. To give feedback about our magazines, please visit immediate.co.uk, email **editorialcomplaints@immediate.co.uk** or write to The Editor, *BBC Sky at Night Magazine*, Immediate Media Co., Eagle House, Colston Avenue, Bristol, BS1 1EN.

abc Audit Bureau of Circulations
17,385 (combined; Jan–Dec 2019)

ISSN 1745-9869



► future travellers will need bees in space. The members of my hive are already being taught to recognise one iconic space travel provider. I am just imagining tiny space suits for these bee-utiful ladies!
Brendan Malone, via email

Viewing in comfort

I have a 200mm Newtonian scope, and the tube cover for the open end has a 50mm removable cap. I find it much more comfortable on the eye to look at the Moon with the cover fitted and the 50mm cap removed. Aside from reducing the brightness, I am not sure what impact this has on performance, especially the ability to resolve small objects. Does the scope, in effect, become a 50mm model, or does it retain the optical abilities of the 200mm mirror?
Tony Teperek, via email

Instagram

Stuartfraser78

Rare noctilucent 'night shining' clouds from last night.
@canonuk @bbcskyatnightmag
#noctilucentclouds #clouds
#astronomicaltwilight
#summersolstice

CORRECTIONS

In April's 'Astrophotography Gallery', the caption for Bob Bowers's picture 'Rosette Nebula' indicated the wrong photo. The correct photo is included in this month's Gallery on page 73.

SOCIETY IN FOCUS

Cornwall Astronomy Society normally meets twice monthly. One of our sites, Degibna Chapel near Helston, is a remote dark-sky location that lends itself to practical observing, with a wonderful blackness resplendent with stars on a clear winter's evening.

With our meetings abandoned due to the COVID-19 lockdown, one of our members suggested trying out a remote meeting on Zoom and a short time later we held our first video-call meeting on 26 March. We started 30 minutes early to give members a chance to iron out any IT gremlins and get their Zoom sessions started.

The whole thing worked well and the experience got as close as we could to our normal face-to-face meetings. In fact, that meeting, and two subsequent ones, all went on longer than normal. During the first meeting we held a group discussion of topical events like comet C/2019 Y4 Atlas and some Messier objects on display.

I and fellow member Fred Deakin were able to slew our scopes to objects under discussion and share the images in real

time on Zoom. This generated all manner of discussion about the object being observed, including practical issues around setting up a scope, accurate pointing and how to capture an image. Other video meetings have included a debate on whether we would be prepared to board the first spaceship to Mars, and reviews of planetarium software like Stellarium.

Zoom meetings have enabled us to continue our friendly club meetings, and in some ways have brought members closer together and engendered a healthy participative atmosphere.

Kevin Reid, member, Cornwall Astronomy Society
► **www.cornwallas.org.uk**

COVID-19
How to get your astro fix from your own home

We pick the best astronomy events and resources available online this month

WHAT'S ONLINE

ONLINE TALKS

The Search for Dark Matter
A quick TED Talk in which astrophysicist Risa Wechsler explores how dark matter is key to the Universe's origins.
bit.ly/RisaWechsler

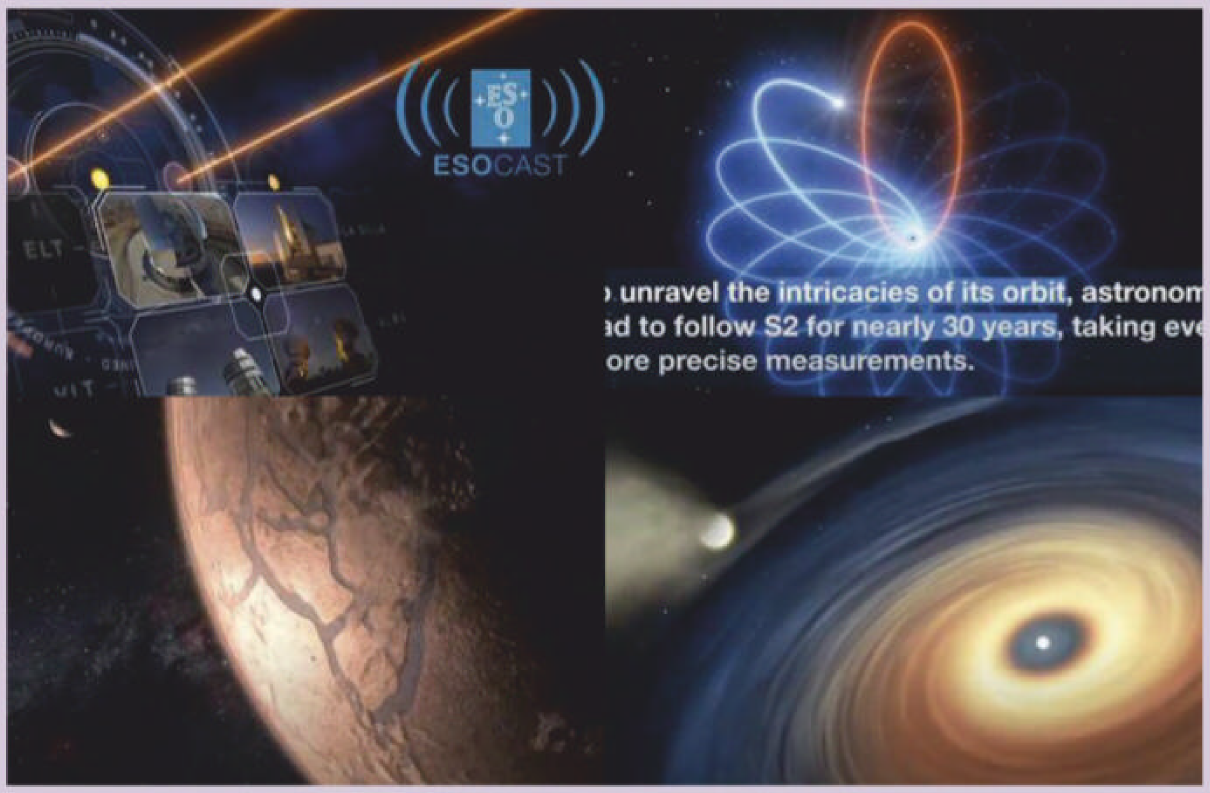
Space junk
Alice Gorman journeys through the abandoned probes, crashed orbiters, discarded rovers and other debris left out in space thanks to human exploration.
www.youtube.com/watch?v=T9NfLol6qEs

Rescuing Hubble
Former Shuttle astronaut Kathryn Sullivan, part of the mission to launch the famous Hubble Space Telescope, shares her experiences of a career in zero gravity.
bit.ly/Hubblerescue

DOCUMENTARIES

Story of Jodrell Bank
Discover how Bernard Lovell's telescope put Britain at the vanguard of radio astronomy.
www.bbc.co.uk/programmes/b06pm5vf

PICK OF THE MONTH



▲ Gain access to a wonderful variety of ESO observations from across the globe

ESOCast

Enjoy bite-sized videos from the European Southern Observatory

The European Southern Observatory (ESO) builds and operates some of the most advanced telescopes in the world, including the Very Large Telescope and ALMA, whose stunning images we often feature in our *Eye on the Sky* pages.

Now you can keep up with revelations from astronomers at ESO via ESOcasts, bite-sized videos with the latest science and news from their observatories in northern Chile.

Films include a spectacular zoom into Betelgeuse, recently revealed to be undergoing unprecedented dimming, a film about the odd orbit of a star around the black hole Sagittarius A*, and a look at extraordinary exoplanets. And, of course, there are enviable shots of the Milky Way above the Chilean desert. As well as superb visuals – some in 4K ultra high-definition – we get snappy explanations of why the observations are important.

ESOcasts are also a good place to follow the construction of the Extremely Large Telescope (ELT), the world's largest optical telescope, due to see first light in 2025.
www.eso.org/public/videos

APPS

Moon Phase Calendar
A handy free app for the Moon's location, phases, illumination, and rise and set times, plus useful information on the Sun too. Available for Android and iPhone.

Solar Walk
The Solar Walk app enables you to take an impressive 3D stroll around the Solar System, zooming in on and even inside planets, comets and moons, and so much more. The app is available for Android and iPhone.

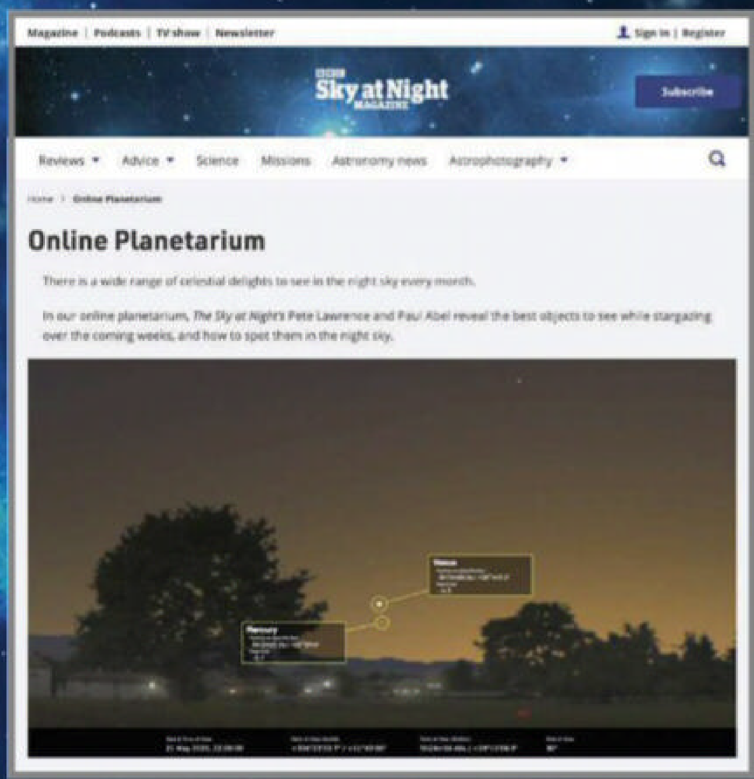
CITIZEN SCIENCE

Be a Dust Detective
Using a virtual microscope, join the Stardust@Home citizen science project to hunt for the first interstellar dust ever brought to Earth. Get started with the web-based training programme.
stardustathome.ssl.berkeley.edu

WATCH OUR ONLINE PLANETARIUM EVERY MONTH!

Stay up to date with all the best night-sky sights thanks to *BBC Sky at Night Magazine's* Online Planetarium. Visit **www.skyatnightmagazine.com/online-planetarium**

NEW AND IMPROVED



Staying up to date with each month's top sights has never been easier thanks to *BBC Sky at Night Magazine's* Online Planetarium. Each month, *The Sky at Night* presenter Pete Lawrence and Paul Abel, Director of the British Astronomical Association's Mercury and Venus Section, host a video tour of the night sky.

As annotated visuals show you where and when to look, they discuss which stars, planets, galaxies and nebulae should be the targets of your observations, as well as particular nights when features on the Moon are best on view in its monthly cycle of phases.

Their expert, lighthearted and entertaining commentary covers what equipment is best suited to each target, famous moments from the history of amateur astronomy, and insider hints and tips from personal experience gathered over many years of observing the starry skies. With a new instalment every month of the year, make *BBC Sky at Night Magazine's* Online Planetarium one of your bookmarks today!

Visit www.skyatnightmagazine.com/online-planetarium to watch

Length of Online Planetarium videos: 15-20 minutes. Online Planetarium visuals provided by kind permission of Stellarium.

The astronomer's forum

FIELD OF VIEW

Stamping through space

Have you ever considered branching out to a new hobby? Philately has much more in common with astronomy than you may have realised

What do you do on a cloudy night when it is impossible to get outside to observe the night sky? Perhaps you read a book or dig out the astrophotographs that you took a few weeks ago but never got around to editing? I like to focus my attention on my greatest and most rewarding hobby: philately. Even on a cold, wet December evening, with the prospect of weeks of cloud ahead, I can gaze upon the wonders of the Universe from the comfort of my sofa.

Philately, or stamp collecting as it is more commonly known, may be something that you associate with older generations, but I can assure you it is quite the opposite. The clear, crisp images bursting with vibrant colour on stamps and first day covers unravel historical and educational tales of famous celestial events and space exploration.

The subjects of astronomy and space exploration have been celebrated on stamps and philatelic material dating as far back as 1887, when Brazil issued a stamp depicting Crux Australis, the Southern Cross. Slowly, postage stamps issued with an astronomical theme spread to other countries including Poland, Japan, the US and finally to the UK in 1966 when the Royal Mail issued a yellow stamp illustrating the Lovell Telescope at Jodrell Bank. Featuring observatories, famous historical astronomers, constellations, space missions and even animals in space, stamps have been issued to commemorate and celebrate achievements and astronomical discoveries in all corners of the world.

My personal collection has grown from being solely focused on astronomy stamps and covers issued by the Royal Mail to now possessing a large catalogue of philatelic material issued in the US. These stamps cover everything from the Moon landing in 1969 to Hubble repair missions and even Mars exploration; researching the stamps and covers, cancellation dates and autographs on the covers has broadened my knowledge and understanding of topics which I previously knew little about.

Katrin displays her stamps at the National Museum of Wales, Cardiff

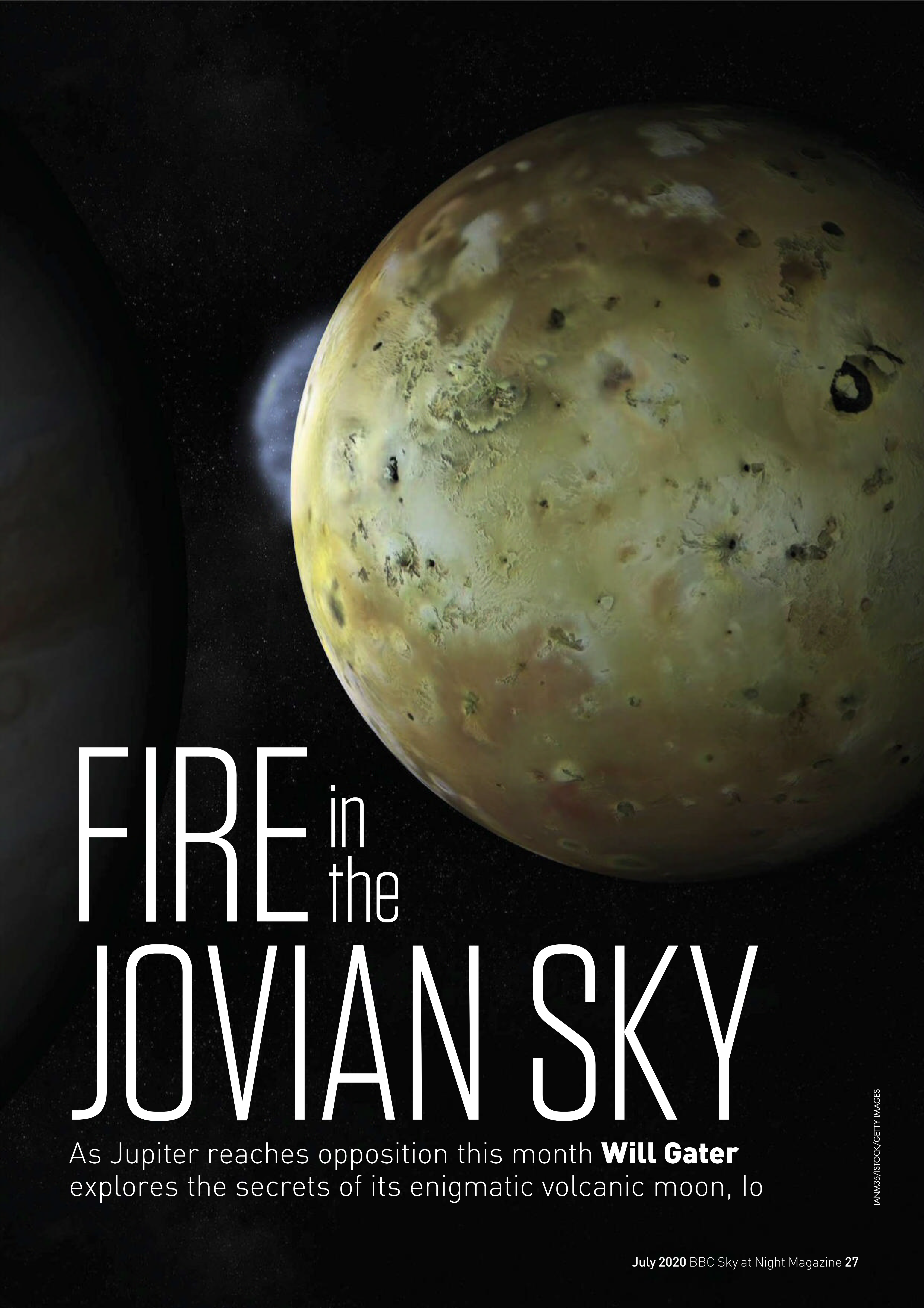
▲ (from top): a US first day cover from 1962 features astronaut John Glenn's signature; Royal Mail marks Halley's Comet in 1986 and the total solar eclipse in 1999

Outreach events provide an opportunity to educate people about astronomy and space exploration through this rather unusual medium. I have taken small parts of my collection to local museums, choosing carefully how to display it in an interesting and engaging manner. From Herschel to Hubble, nebulae to Neptune, I take great joy in delighting visitors with this miniature world of stellar information. STEM Through Stamps, as I like to call it, is an original and surprising way of educating astronomers. People are amazed that the story of Halley's Comet can be told with just four colourful stamps on an ordinary looking envelope.

For over a hundred years, stamps have been issued commemorating and celebrating the many facets of astronomy and space exploration. Why not start your own collection by researching the subject on the internet or join an astronomy stamp society to immerse yourself in a new way of learning about your favourite subject? This unique and fascinating branch of thematic philately will take you on a breathtaking journey into the Solar System and beyond, and it won't cost the Earth.

Katrin Raynor-Evans is an amateur astronomy writer and Features Editor for the Society for Popular Astronomy.

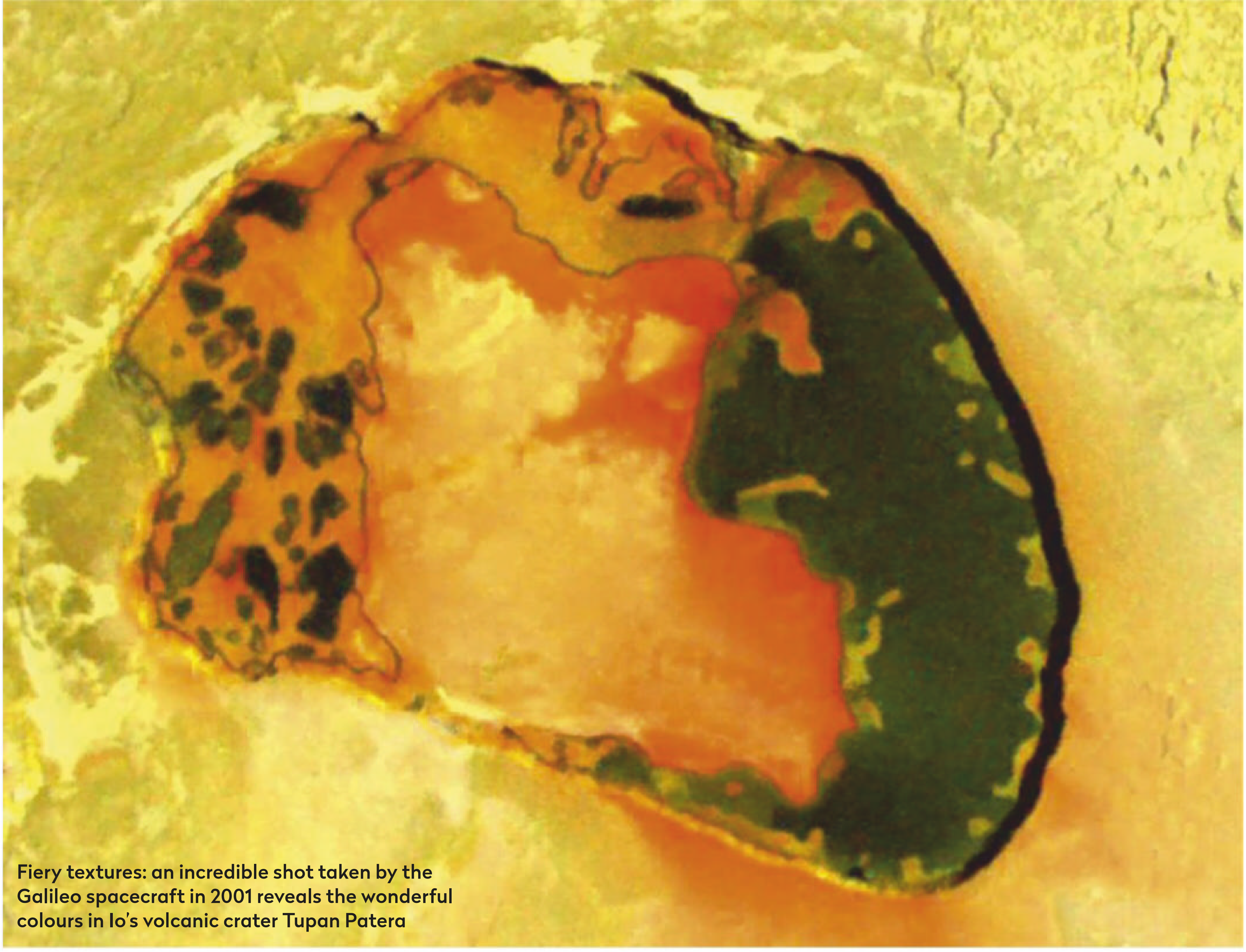
Great ball of fire: Jupiter's moon Io is one of the most volcanically active bodies in our Solar System



IANM35/ISTOCK/GETTY IMAGES

FIRE in the JOVIAN SKY

As Jupiter reaches opposition this month **Will Gater** explores the secrets of its enigmatic volcanic moon, Io



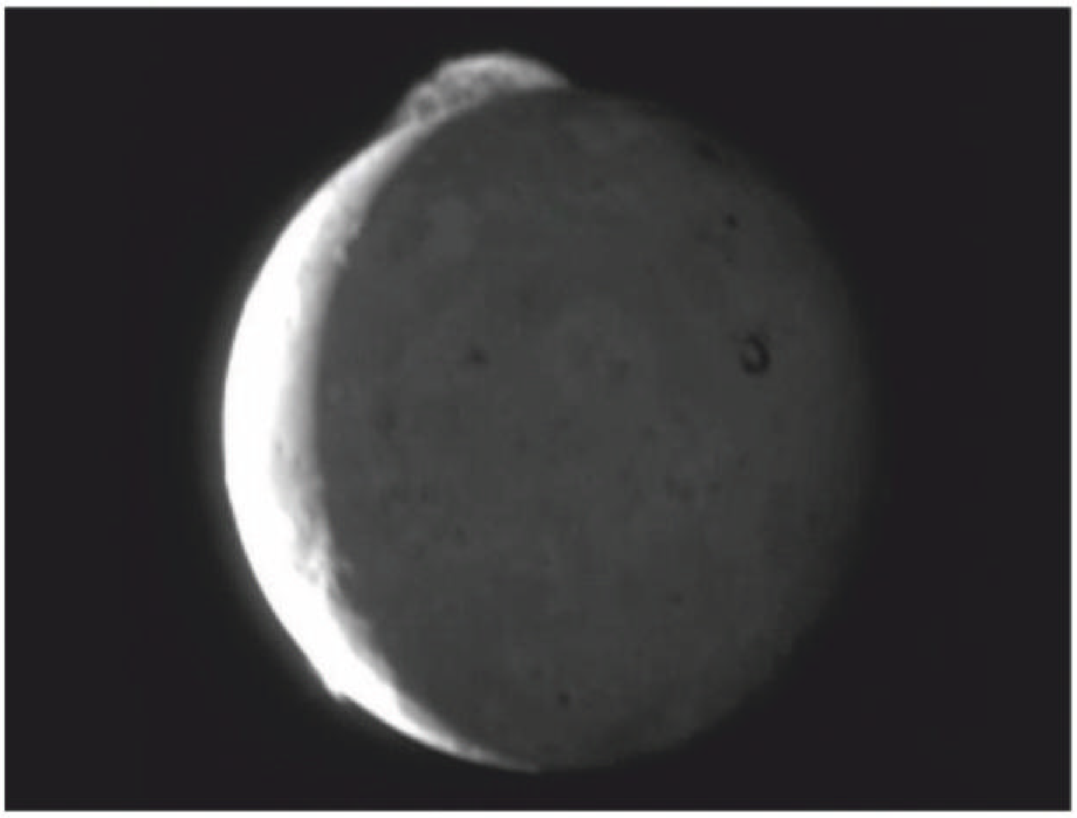
Fiery textures: an incredible shot taken by the Galileo spacecraft in 2001 reveals the wonderful colours in Io's volcanic crater Tupan Patera

With Jupiter at opposition this month, we have a chance to observe a planet that, along with its moons, has spent centuries in the limelight of scientific study. Jupiter's icy moons Europa, Ganymede and Callisto, continue to attract immense interest, not least because liquid water may be sloshing under their frozen shells. But there's another Jovian satellite every bit as interesting as its ice-encrusted compatriots: Io.

The third largest of the four 'Galilean' moons, Io is a volcanic hell – a world stained with putrid hues of yellow, brown and red. It is, in many ways, the antithesis of the likes of Europa. Yet that hasn't stopped researchers from poring over every detail of its surface. With ever improving ground-based technology and the Juno mission currently in the Jovian system, new insights into the activity of this pockmarked moon are being revealed every day. There are even calls for a dedicated mission to explore this oddity among the outer planets.

One researcher whose work has recently attempted to shed light on Io's violent volcanism is Professor Katherine de Kleer of the California Institute of Technology. The varied colours across Io's famously blotchy disc are almost all a result of some form of volcanic activity, she says. "It's all different sulphur-containing molecules that produce those different colours. Except for the dark regions – the black and grey deposits and lava flows are probably silicate."

The volcanoes that create Io's striking surface are littered all over the moon. The Galileo probe – which took what are still the best close-up images of Io when it swooped past in the late 1990s and early 2000s – caught sight of glowing lava flows. Meanwhile, other missions – including New Horizons and Hubble – have imaged vast, dome-shaped plumes of material erupting over Io's limb.



▲ A giant volcanic plume from Io's Tvashtar volcano was spotted by NASA's New Horizons spacecraft in 2013

Heat seeking

Hundreds of volcanoes are located across Io's globe. Sometimes they stand out because scientists can detect their heat as an infrared glow, while others can be revealed thanks to tell-tale surface colouration. "You assume that a dark lava flow is young because▸

NASA/JPL/UNIVERSITY OF ARIZONA, NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/SOUTHWEST RESEARCH INSTITUTE, WILL GATER X 6

Image Jupiter and Io with a high frame rate camera

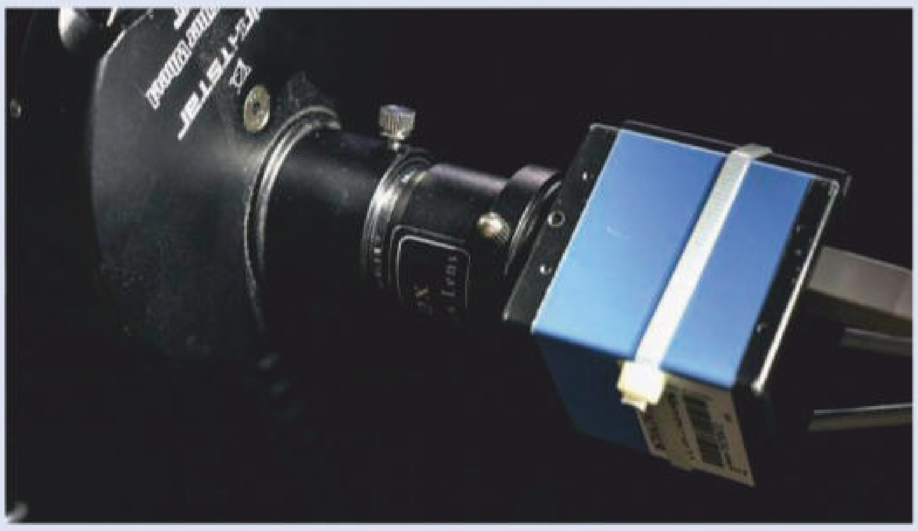
It takes patience and a clear sky to capture the gas giant and its moon, Io

Step 1: Check when Io will be visible

Consult the Jupiter's moons diagram on page 45 to find a night when Io's well placed for imaging. Look for a time and date close to Jupiter's opposition when Io is positioned away from the planet's disc. Experts can capture the Galilean moons when they are 'transiting' in front of Jupiter, but we want Io to be easily detectable.

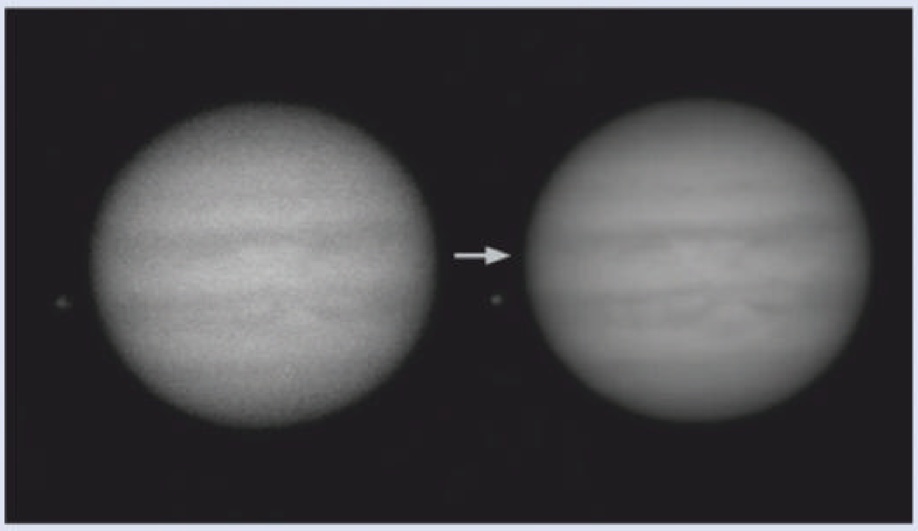
Step 2: Check collimation of your optics

We need everything to be on our side to get good data of Io. This means clear, still skies and our optical equipment needs to be working to its full potential too. Before you start imaging, check your telescope's collimation – see **www.skyatnightmagazine.com/advice/how-to-collimate-your-telescope**.



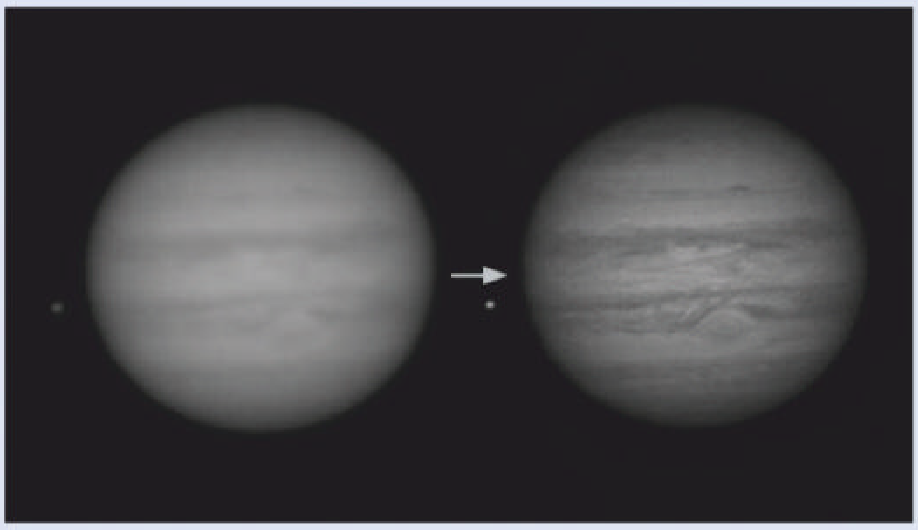
Step 3: Focus and capture data

Spend time focusing the image; it can be easier to concentrate on how well-defined Jupiter's cloud band detail is, as the small moons can jump around and blur under poor seeing. Then capture an AVI video. If you're imaging with a monochrome camera, capture using red, green and blue filters to make a full colour image later.



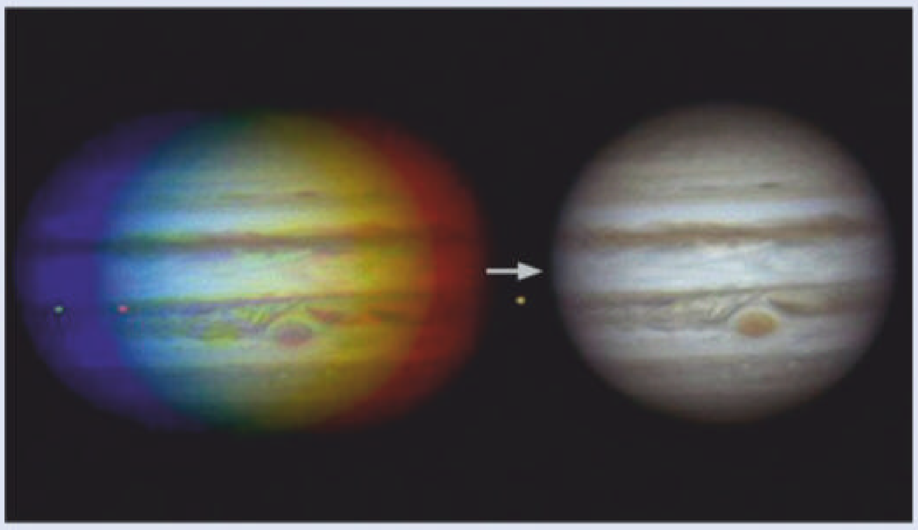
Step 4: Sift and stack data

If you've been imaging with a one shot colour camera or webcam you can select the best frames from the video and stack them in software like AutoStakkert! or RegiStax. Imagers with monochrome cameras will need to do this for each filtered video. Stack at least a few hundred frames to create a smoother final image.



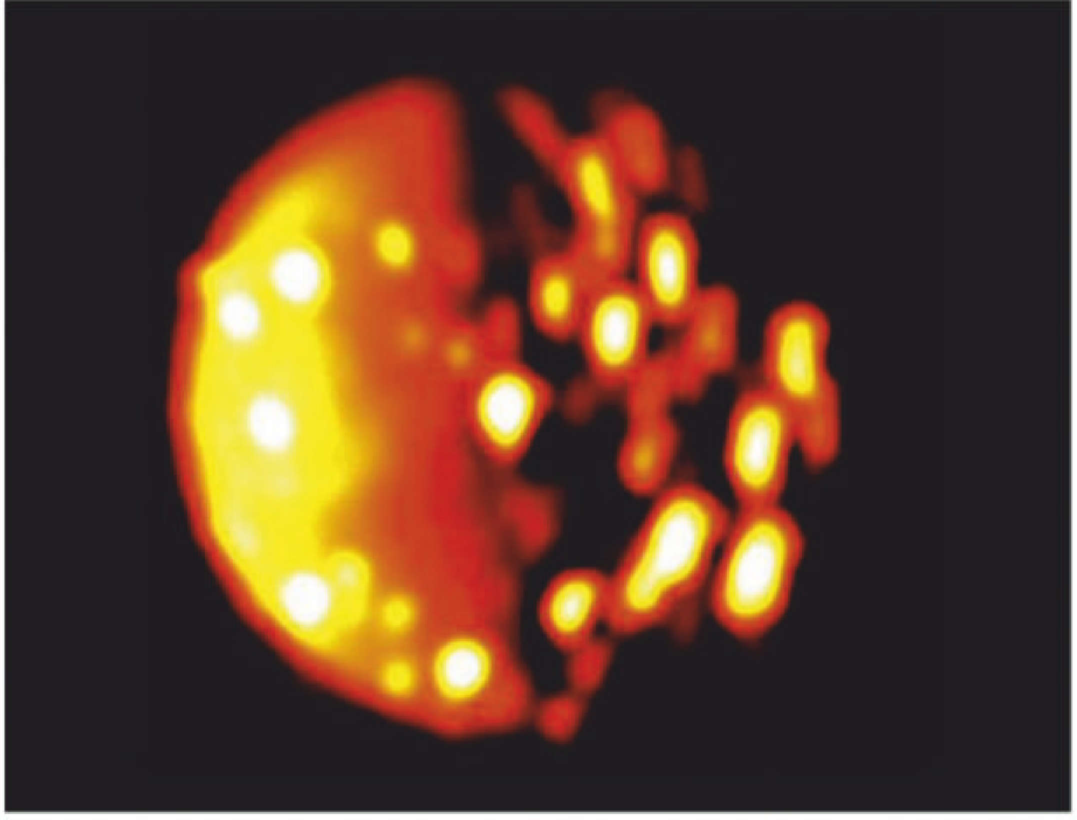
Step 5: Sharpen data

The next step is to enhance the image(s) produced in Step 4. We do this using RegiStax's 'wavelet' sharpening filters, applying small adjustments using the different wavelet 'sliders'. Be careful though – too much sharpening can look worse than a soft image. Apply the 'Do All' function, then save the result as a 16-bit PNG file.



Step 6: Align RGB channels (if imaging in mono)

One shot colour images can now be adjusted for contrast, etc. For monochrome, combine your three filtered images in Photoshop. If Io has moved between captures make two copies of the full colour layer and nudge the offset colour channels of Io in one until they align. Use a layer mask to blend the layer showing Jupiter.



▸ Hot spots: an infrared image of Io taken by Juno in 2017 highlights its volcanic activity; the brighter colours indicate hotter temperatures

▸ it still has to be warm for it to stay dark," explains de Kleer. "If it were cooled completely the sulphur dioxide would freeze out of the atmosphere on to it and it wouldn't be dark anymore. So even where you don't see the infrared emission, you can infer that something's been active within the past couple of years."

De Kleer's own work has involved looking at Io with powerful ground-based facilities, like the Keck Observatory telescope in Hawaii. By observing the moon at infrared wavelengths, de Kleer and her colleagues were able to get a very different view of Io. "The disc is bright because the sulphuric frosts on its surface are reflecting sunlight," says de Kleer. "But then on top of that you see these really bright little spots all over Io's surface. These spots are infrared emission from the heat coming off these individual active volcanic regions."

The Juno spacecraft – currently whirling around Jupiter – also looks at Io in infrared; in imagery captured in 2017, it was able to detect signs of a glowing patch of volcanic activity where there seemingly hadn't been one before. This thrilling level of geological dynamism is something that can be seen in Earth-based infrared observations too. "Taking pictures from night to night you can see the different volcanoes [that] are active or not active," explains de Kleer. "They're giving off different amounts of heat and you can see that by just observing several nights in a row at a telescope; you can see how it's changing."

Volcanic activity

If we were able to get up close to these volcanoes, the sulphur deposits may appear similar to those seen around volcanic features on Earth, such as in Lassen Volcanic National Park and Yellowstone in the US, expains de Kleer. "You can probably imagine something like that but scaled up," she says.

The actual shapes of the volcanoes are likely to be a far cry from towering, pointed peaks, however, due to the nature of the material they form from. "We think the magmas that are erupting on Io are at the upper end of the temperatures for things we see on Earth – maybe hotter," says de Kleer. This high temperature, along with the magma's lower silica content compared to Earthly analogues, means that when lava does break out onto Io's surface it's thought to be particularly runny, and it can flow over long distances rapidly.

What, then, creates Io's volcanism in the first place? It's thought to arise from the gravitational dance the moon performs with Jupiter, Europa and Ganymede; this creates a force that repeatedly pulls and squashes the 3,640km-wide Io.

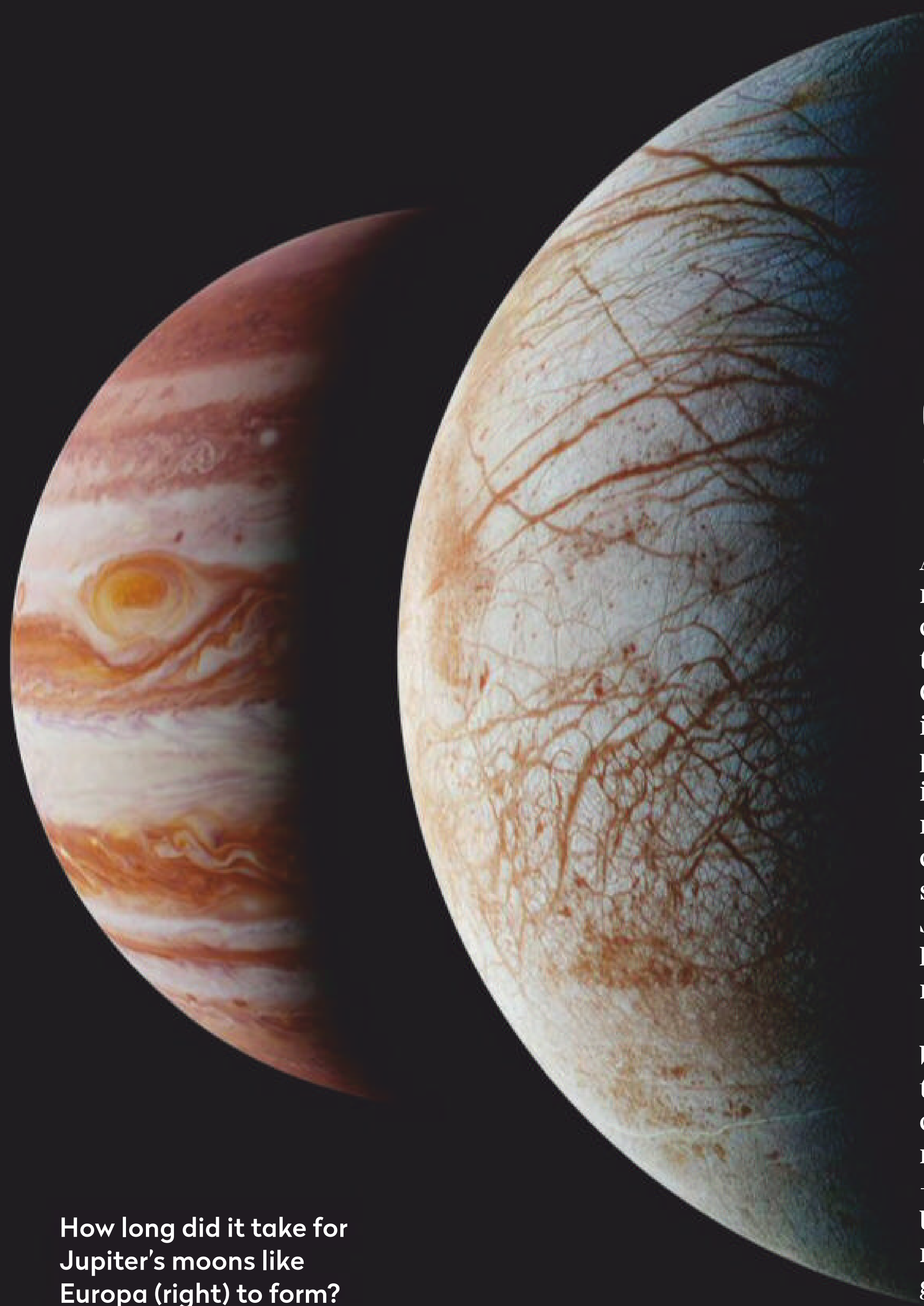
▲ Seeing sulphur: if you were able to stand on it, Io's surface might resemble California's Lassen Volcanic National Park

"You have this pretty rapid deforming of its shape every couple of days that generates friction in its interior and produces heat," explains de Kleer. "It's sufficient to melt rock."

One of the most spectacular results of the molten mayhem going on under Io's surface is the volcanic feature in the moon's northern hemisphere known as Loki Patera. This huge magma lake measures some 180km across and has been the focus of recent research by de Kleer and her colleagues.

Using the Large Binocular Telescope (LBT) – sited in Arizona, in the US – the scientists watched as Jupiter's moon Europa passed in front of Io. Ordinarily it's tricky to resolve detail on Loki Patera when observing in infrared light from the ground, but the passage of Europa allowed them to perform a clever observation. As Europa gradually obscured

One of the most spectacular results of the molten mayhem under Io's surface is the volcanic feature known as Loki Patera



How long did it take for Jupiter's moons like Europa (right) to form?

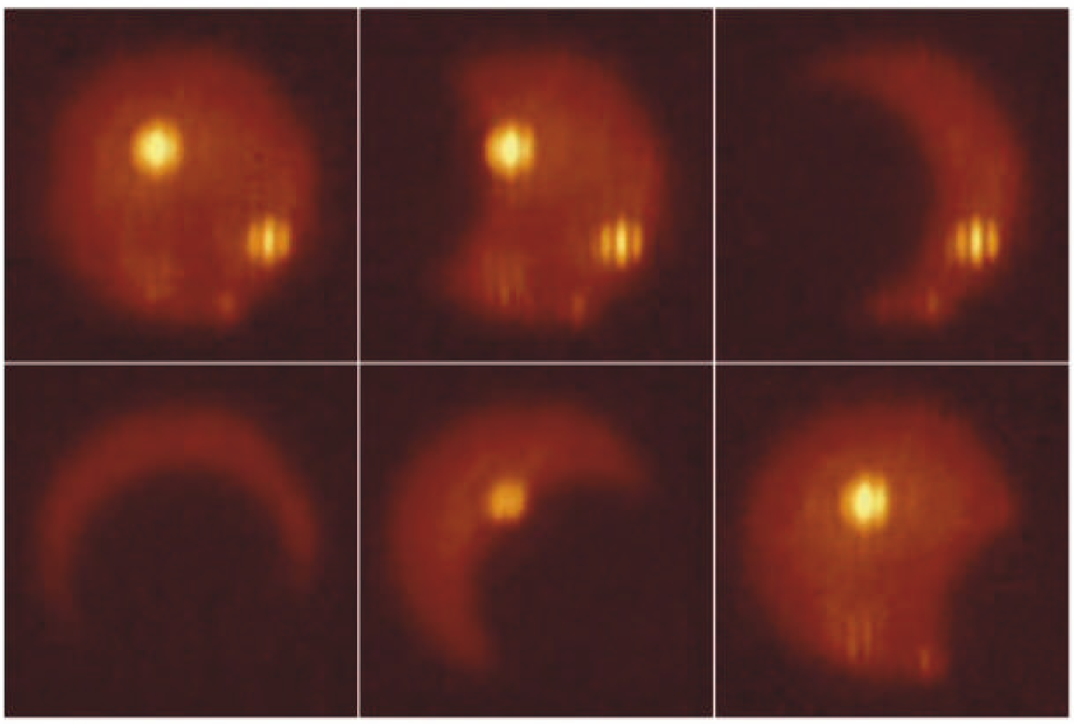
Building Jupiter's moons

One of Jupiter's biggest mysteries is the formation of its large moons

As scientists consider sending missions to Jupiter in the coming years, one question that remains about the Galilean moons, Io included, is how did they form? The prevailing theory suggests it could have been a relatively rapid process; the moons combined from kilometre-sized objects encircling Jupiter in as little as a hundred thousand to a million years.

Now, though, new research by Dr Yuhito Shibaike, at the University of Bern, and colleagues argues the process may have been much slower – perhaps taking something like 10 million years. In this new theory the chunks gathering together would have been smaller too, measuring only centimetres across.

Among the evidence for the new theory is the fact that Europa actually possesses relatively little water, suggests Shibaike. "In our scenario, Europa got water only after the gas disc became cooler, at the very last moment of the formation, resulting in the very small amount of water on the moon," he explains. "However, if the accreting bodies are large, only the water on their surfaces is lost and most of the water remains inside them. Therefore in the classical scenario, Europa should have got a lot of water through the entire formation period."



▲ **Section by section: as Jupiter's moon Europa passed in front of Io it allowed scientists on Earth to create a detailed map of Loki Patera, a bright volcanic feature on Io's surface, which is visible in the top left of the images**

the vast volcano, the team could measure the infrared glow from relatively small sections of it – since they could work out precisely which bits were visible, and therefore glowing, at a given moment. This, coupled with the power of the LBT's optics – which function as if they were one immense 23m-wide mirror – allowed de Kleer and her fellow researchers to perform something akin to a 'scan' of the infrared signature of Loki Patera (see set of six images, above).

The infrared 'map' the team were able to create is part of a broader effort to try to figure out the nature of what de Kleer calls the 'plumbing system' that joins Io's depths to its surface. "What that connection system looks like is pretty much totally unknown. And to say anything about what that looks like you really have to get very good spatial resolution on a single volcano," she says.

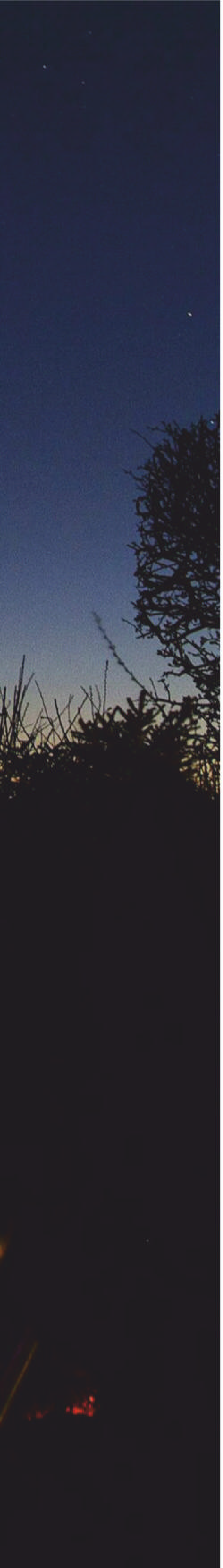
While researchers continue to watch Io from the ground and in space, there are those who are also pressing for a dedicated mission – currently referred to in preliminary proposals as the Io Volcano Observer (IVO) – to travel to Jupiter in order to explore the moon in much greater detail.

"It would be able to get a totally different type of information and be very complementary," explains de Kleer. "When you're in the system you can measure the gravity field and magnetic field and those tell you about the interior of an object in a way that nothing else really can."

As planetary scientists wait to see if they will be granted their mission, two things are clear: Io's volcanoes show no signs of settling down; and just as its surface is destined to continue changing, so will our understanding of this distant, enigmatic, world.

Will Gater is an astronomy journalist and science presenter based in the UK. Follow him on Twitter at: @willgater or visit: willgater.com

Mars in focus: the salmon-coloured planet will be a prominent beacon in our autumn skies



Get ready to observe the RED PLANET

You may be missing bright Venus, but one of the best appearances of Mars is approaching. **Pete Lawrence** looks ahead to its favourable opposition in October

The night sky in the first half of 2020 was dominated by brilliant Venus in evening twilight. With Venus now in the morning sky, the low southern planets Jupiter and Saturn have taken up the reins in the evening sky. Later this year, however, there's a big planetary event to look out for as the Red Planet appears high and bright in evening skies. Indeed, this autumn we'll see the best opposition of Mars for many years to come.

A planet is said to be in opposition when the Earth lies directly between it and the Sun. As the planet sits in the opposite part of the sky to the Sun, it's positioned closest to Earth for its current 'apparition', or period of visibility. It's a good time to observe a planet, because it will appear bigger than usual. Opposition is a big deal for Mars because it's a long way from Earth for most of the time, looking dim to the naked eye and small when viewed through a telescope. But as the distance between our worlds shrinks, Mars brightens considerably, while expanding in size through the eyepiece of a scope to be large enough for surface detail to be seen easily.

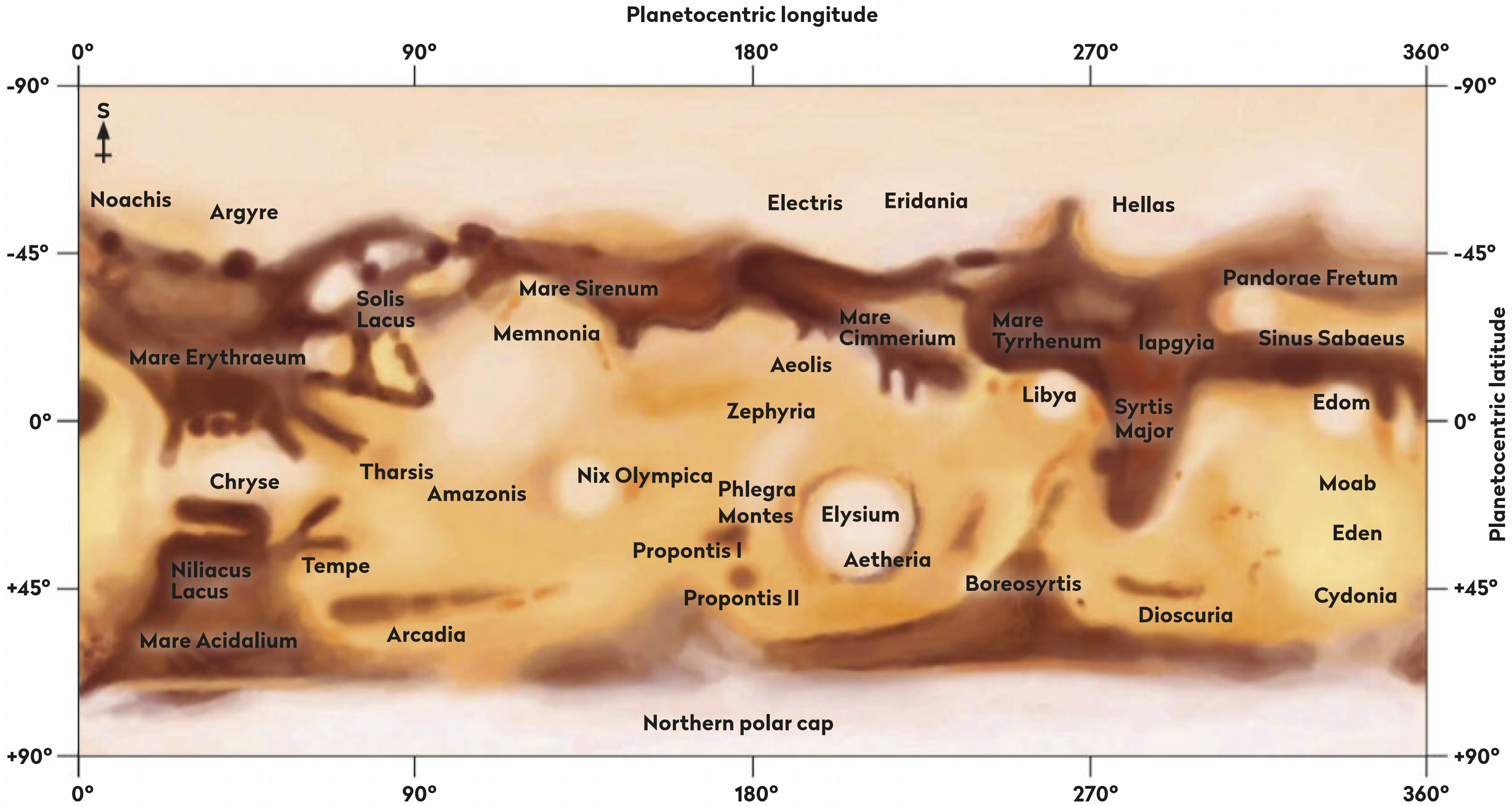
Mars oppositions occur every two years and two months (or to be precise, every 779.94 days) and this year opposition falls on 13 October. In the run up to this date Mars will show a gradual but dramatic brightening, surpassing Jupiter's brilliance on 24 September to become the second brightest planet after Venus. And it will remain bright for weeks afterwards, well into November. Indeed, mid-November may be the time to observe Mars if you have a young family or a fledgling interest: even though Mars won't be as bright then, it will reach its highest position in the sky in the early evenings, which is a convenient time for many observers. To the naked eye the salmon pink colour is incredible when it becomes bright; it's an unmistakable sign that you are looking at the Red Planet.

Bright pairings

Just like Venus earlier this year, there will be some great conjunctions between Mars and the Moon to feast your eyes on. Just after 01:00 BST on 12 July (midnight UT on 11 July), mag. –0.7 Mars sits 3˚ west-northwest of a waning gibbous Moon. On 9 August at 04:30 BST (03:30 UT), mag. –1.3 Mars is located 3˚ northeast of the waning gibbous Moon. This is an interesting conjunction because it should be possible to stay with both objects after sunrise: just prior to setting at 11:00 BST (10:00 UT), they appear 1.1˚ apart. ▸

E This month, on the night of the 11th/12th, Mars and a waning gibbous Moon rise together

ALL PICTURES: PETE LAWRENCE



▲ An albedo map of Mars, showing contrasting areas of surface brightness, reveals the most visually prominent light and dark features

▸ Mag. –1.9 Mars and a waning gibbous Moon will be 0.7˚ apart at 05:30 BST (04:30 UT) on 6 September, a lovely naked-eye pair. Keep with them and by 07:00 BST (06:00 UT) they will be just 0.4˚ apart. You'll need binoculars to see the closest approach as it happens when the Sun is up. Another opportunity occurs on 3 October, when mag. –2.5 Mars sits 1.1˚ from a virtually full Moon at 06:30 BST (05:30 UT). This will be the last close conjunction of Mars and the Moon for 2020.

Although useful for conjunction viewing, binoculars won't reveal much more Martian detail than you see with your eyes, the planet appearing as a small, bright, salmon pink disc against a background star field. To see features on the Red Planet, you'll need a scope with a front lens that's at least 75mm in diameter.

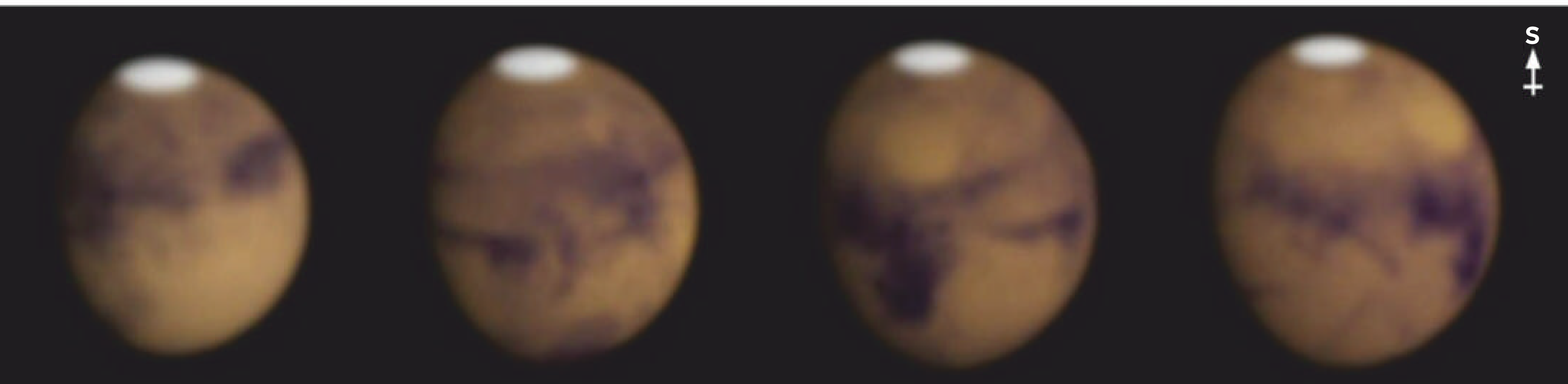
With a telescope, the changes to Mars's appearance in the run up to opposition become very evident. On 1 July it appears 11 arcseconds across, increasing to nearly 15 arcseconds at the beginning of August. By the start of September, Mars appears 19 arcseconds across and on 25 September the planet will have doubled its apparent size from 1 July, appearing at 22 arcseconds across. It maintains this size through to the middle of October, dropping to 20 arcseconds by 1 November.

The planet's largest apparent size occurs when it is closest to Earth and this typically occurs a few days adrift of the opposition date. For 2020, Mars is closest to Earth on 6 October and appears 22.6 arcseconds across, a week before opposition on the 13th.

In the pink

Through a telescope, Mars can be slow to reveal its detail at first. Features are there but you may find them hard to see, especially if you're new to observing the Red Planet. It's not uncommon to see a pink blurry blob at first, but give yourself time to settle into the view and you'll gradually see more. ▸

▼ Run up to opposition: simulated telescopic views of Mars in its best viewing position reveal how its apparent diameter increases gradually in July



JULY WEEK 1
Approx. 3:30 BST (02:30 UT)
Altitude: 22°
Apparent size:
11-12 arcseconds

JULY WEEK 2
Approx. 3:30 BST (02:30 UT)
Altitude: 25°
Apparent size:
12-13 arcseconds

JULY WEEK 3
Approx. 3:30 BST (02:30 UT)
Altitude: 28°
Apparent size:
13 arcseconds

JULY WEEK 4
Approx. 3:30 BST (02:30 UT)
Altitude: 30°
Apparent size:
13-14 arcseconds

Unequal oppositions

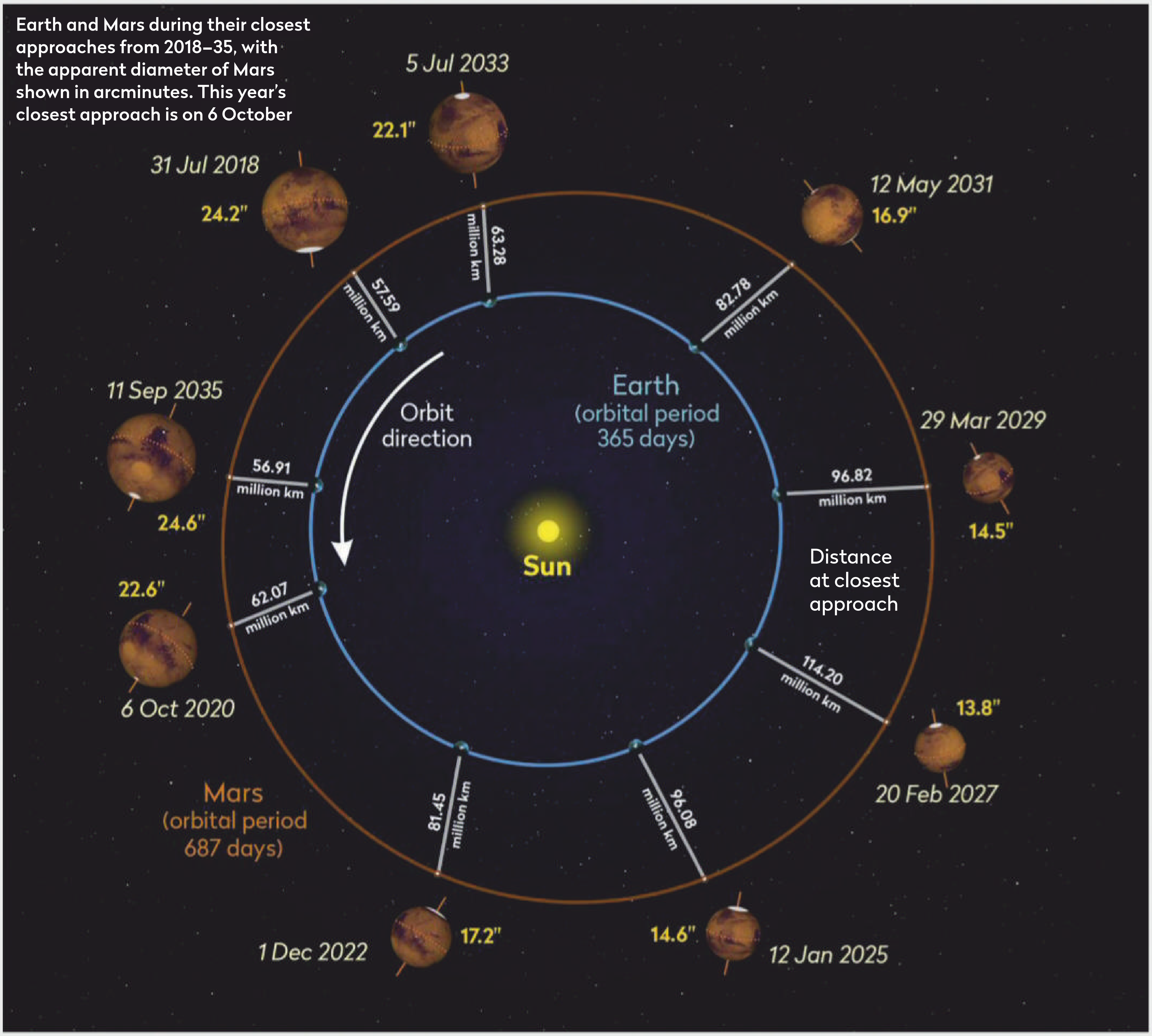
The Red Planet reaches opposition every few years, but there are also cycles that play out over longer periods of time

Not all close approaches of Mars are the same: some are distinctly better than others. The maximum apparent size of Mars varies in a cyclical fashion through subsequent oppositions, because the orbits of Earth and Mars are not exactly circular; they're elliptical. When Mars is very far from opposition, its disc can shrink as small as 3.5 arcseconds – similar to the apparent size of Uranus. In contrast, at a really favourable opposition the largest size the Red Planet can reach is 25.1 arcseconds, and at the 2018 opposition we saw the apparent diameter of Mars get very close to that, at 24.2 arcseconds.

For the UK at least, the 2018 opposition took place when Mars was low in the sky. This was a 'perihelic opposition', one taking place when Mars was close to (technically within 90° of) perihelion, the position where the planet has its smallest orbital distance from the Sun.

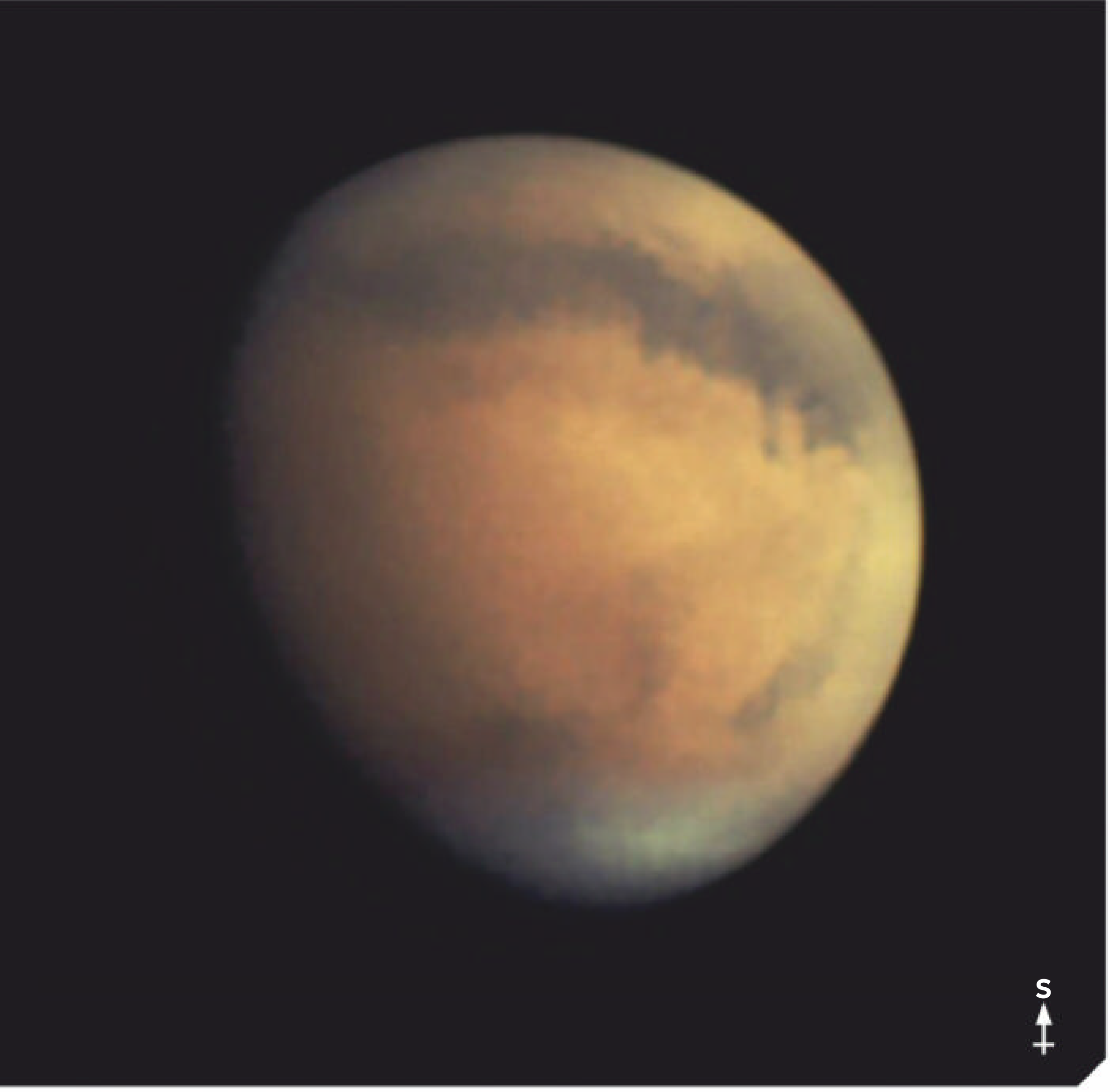
The maximum size of Mars in 2020, also technically a perihelic opposition, will be 22.6 arcseconds, smaller than the 24.2 arcseconds presented during 2018, but still a reasonable value. Opposition diameters will continue to shrink for a number of future oppositions. At the 2022 opposition, the biggest the Red Planet's disc gets is 17.0 arcseconds, while the 2025 opposition presents a 14.5 arcsecond disc. It shrinks further still for the 2027 opposition, when it will appear 13.8 arcseconds across.

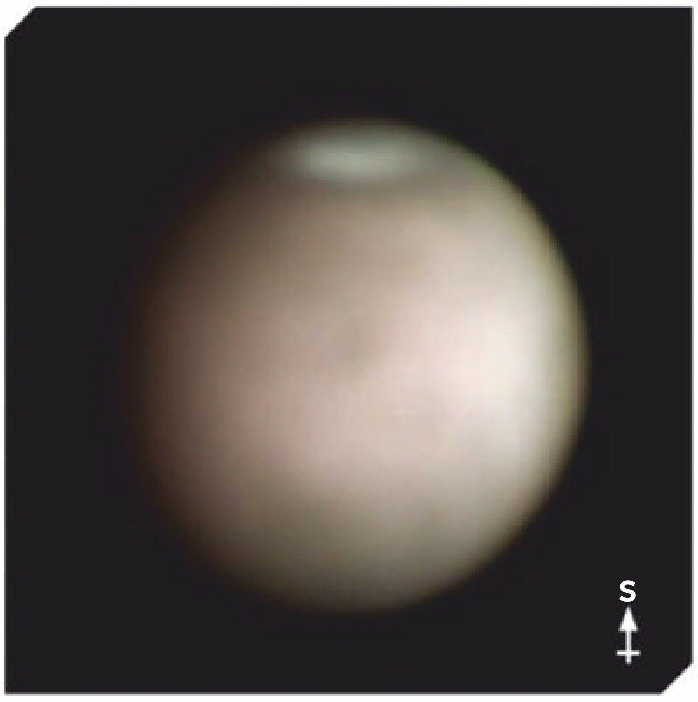
With these forecasts in mind, we can see that the 2020 opposition of Mars will be the most favourable for UK viewing for some time – it won't be this big again until 2035.

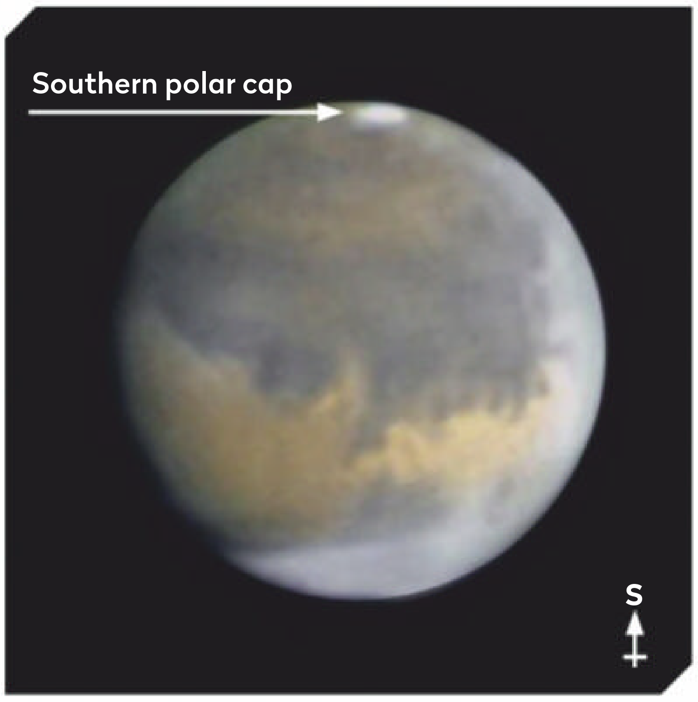


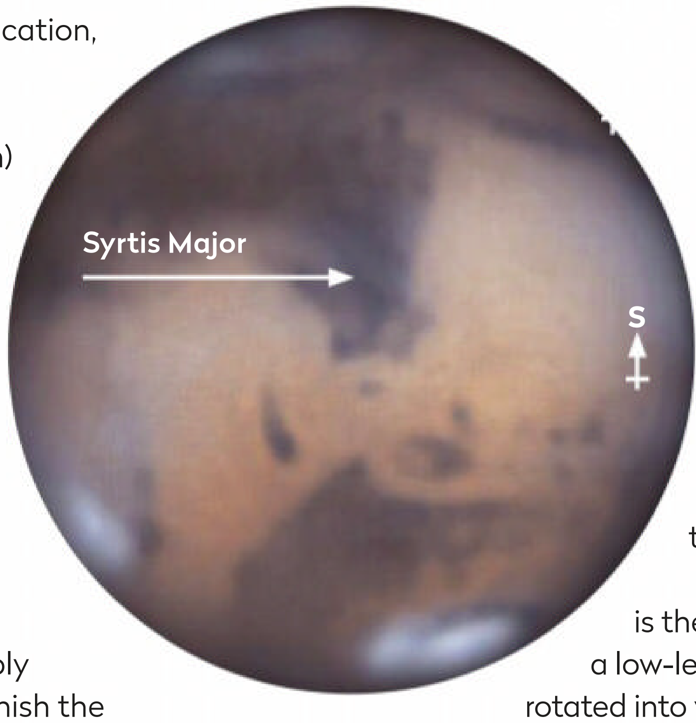
Earth and Mars during their closest approaches from 2018–35, with the apparent diameter of Mars shown in arcminutes. This year's closest approach is on 6 October

PETE LAWRENCE X 5, ALIX BRISKHAM









▲ **Mars in detail: (clockwise from top, left): the Red Planet will have a gibbous phase in July; a Martian dust storm envelops the planet in 2018; the southern polar cap can be seen to shrink as Mars approaches perihelion; the triangular Syrtis Major photographs well**

ALL PICTURES: PETE LAWRENCE

▸ Start using a low magnification, say 25x the size of your telescope's aperture in inches. For a 4-inch (25mm) this means starting off around 100x. Increase the magnification if the view is steady. As a general rule, the maximum magnification for any size of telescope is 50x its aperture in inches, but atmospheric conditions rarely make this possible: going too high under wobbly conditions will simply diminish the quality of the view.

With each magnification, give your eye time to get used to the view. Notice the edge of the planet first. In the run up to and from opposition, Mars appears gibbous in shape – more than half but less than a full circle. In July, although the planet's only half the size it'll appear in October, the southern polar cap should be obvious (see July views of Mars on page 34). During the 2020 opposition, it's Mars's southern hemisphere and polar cap that's tilted towards us. Mars gets closest to the Sun in its orbit, a point called perihelion, on 3 August. As it approaches perihelion, the extra warming it receives will cause the southern polar cap to shrink.

All features great and small

As Mars gets larger, its surface detail should be easier to see. As well as the bright southern polar cap, the planet presents areas of light and dark, representing deserts and exposed rock. These are known as albedo features: areas that appear bright or dark due to the amount of light they reflect (see map on page 34). The larger and darker an albedo feature, the easier it is to see through a small telescope.

The most prominent dark feature is the V-shaped form of Syrtis Major, a low-level shield volcano. When it has rotated into view, the 'point' of Syrtis Major points north, appearing to extend quite far towards the northern edge of Mars during the 2020 opposition. Between the southern boundary of Syrtis Major and the southern polar cap lies the Hellas Basin. This 2,300km diameter basin is one of the largest impact craters in the Solar System.

Hellas can sometimes appear bright due to clouds that form in the basin. Although Mars has a very thin atmosphere, there's enough to support weather and the formation of hazy clouds. Bright orographic clouds form when the Martian atmosphere is forced to a higher altitude and can be particularly noticeable over the peaks of the vast volcanoes that sit on Mars's Tharsis plain. As the Red Planet approaches perihelion on 3 August, it's also worth keeping an eye out for Martian dust storms. Fuelled by the extra energy delivered by the Sun, these sometimes remain quite contained on the surface but may also spread into a planet-obscuring veil.

If you're observing Mars from one night to the next, be aware that the planet's rotation period is almost

Although Mars has a very thin atmosphere, there's enough to support weather and the formation of hazy clouds

40 minutes longer than Earth's, at 24 hours, 39 minutes and 35 seconds. This means that features are centrally located on Mars's disc 40 minutes later on each consecutive night. Imagine looking at Mars one night and seeing a dark feature at the centre of its disc (what's known as Mars's central meridian). The following night at exactly the same time, that feature would appear slightly further east and take an extra 40 minutes to reach the central meridian once again. The night after that, viewing at the same time, the feature would take 80 minutes to reach the central meridian. It looks as if Mars resets position each consecutive night, giving you just a glimpse of extra new surface along the western limb before it then does a re-run of what you saw on previous nights. Eventually of course, you do get to see the whole globe, but this 'reset and re-run' can catch observers out.

Pete Lawrence is an experienced astronomer and a co-host of *The Sky at Night*

True colours

The light from Mars is predominantly shifted towards the redder end of the spectrum, which works in our favour because longer wavelengths are less susceptible to being blurred by our turbulent atmosphere. You can improve what you see visually with a telescope by using filters. Visual filters are normally identified by their Wratten numbers. These may be written as W followed by a number and possibly a letter. Although the numbers represent specific colours, there is no sequence to them; W16 is yellow-orange, W18B is very deep violet and W21 is orange for example. The letters sometimes found after the number represent increasing strength of filter.

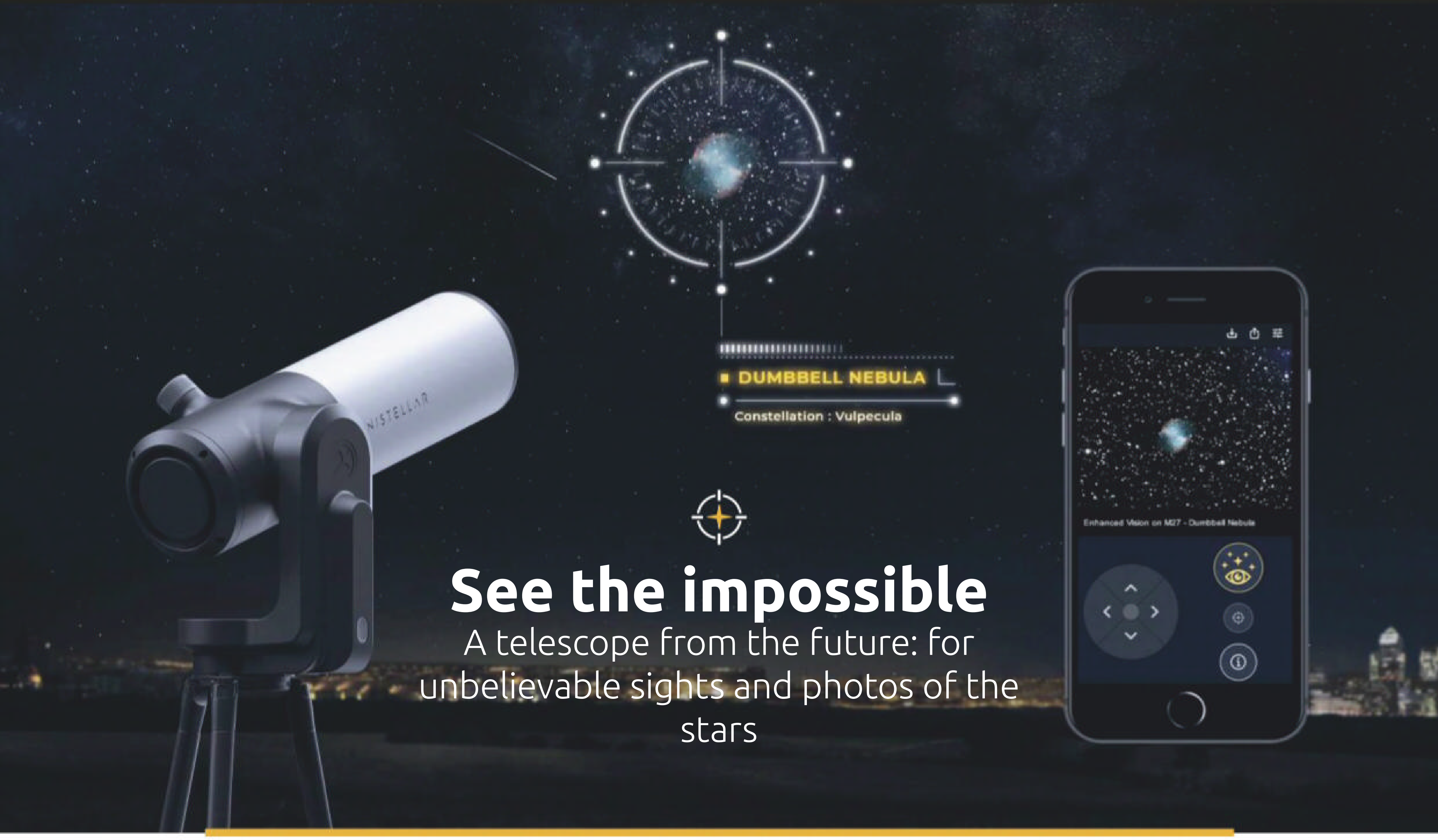
Yellow filters (W12, W15) will tend to make the lighter, desert regions appear brighter and brown/blue regions darker. Orange (W21, W23A) also helps increase the contrast between the light deserts and dark exposed rocks, further cutting through the weak Martian atmospheric haze. Red (W25, W29) enhances the contrast yet again and is excellent for defining the boundaries between regions. Orange and red are also good filters to use for observing Martian dust storms, if they appear.

A green (W57) or blue-green (W64) filter is good for showing seasonal features such as frost patches, fog and irregularities along the edge of the polar caps. Blue (W80A, W38, W38A), deep blue (W46, W47) and magenta (W30, W32) are all good colour filters for detecting Martian weather in the form of white clouds or limb hazes; magenta in particular is good for seeing detail in the Martian polar regions.

The last time Mars was at opposition in 2018, we got a view of it with a large apparent size, the best for some time and larger in fact than this year. But the planet was low to the horizon as seen from the UK and this spoilt the view for many. This year the Red Planet will get to a much higher altitude in the night sky, reaching at least 40° in altitude, in the constellation of Pisces. With a maximum apparent size only fractionally smaller than that seen in 2018, this makes 2020 the year to get acquainted with this fascinating world.

▼ A good selection of coloured filters are useful additions when observing Mars

UNISTELLAR



See the impossible

A telescope from the future: for unbelievable sights and photos of the stars

What do you get when you combine a telescope with modern technology in order to create something new? A marvel for endless journeys through the Universe. Experience for yourself how even faint deep sky objects appear bright, clear and in full colour in the eyepiece. A cross between visual observing and fully automated photography. Sounds too good to be true? It has been made possible through a combination of a telescope with an OLED screen and a state-of-the-art sensor. Welcome to the telescope world of the future. With the new Unistellar eVscope, the future has already arrived.

Fast aperture
The parabolic primary mirror produces an image with no spherical and chromatic aberrations.

Integrated astro-camera
The highly sensitive Sony IMX224 CMOS sensor enables the observation of even faint celestial objects.

Modern OLED screen
The night sky is projected through the eyepiece from an extremely high-contrast screen. You will see nebulae and galaxies in detail and in colour!

Autonomous Field Detection
This outshines conventional GoTo! Thanks to the eVscope's sophisticated plate solving process, it can analyse stars in the field of view in seconds. So it automatically points to every observing target.

Easy to use
With the Unistellar app (Android/iOS) you have complete control – uncomplicated and without irritating cables.

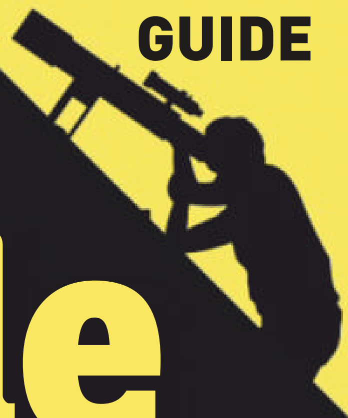
Enhanced Vision Technology
The eVscope shows not only the image from a single moment, but collects light over longer periods of time. So you can make even faint celestial objects visible! Activate the live stacking and watch the development and optimisation of the field of view in real time.

Conventional telescope

eVscope

Unistellar eVscope	Article No.	Price in £
114/450 astrograph incl. tripod		
Weight 9.0 kg (19.8 lbs)	63955	2,630.00

16-PAGE STARGAZING GUIDE



BBC Sky at Night MAGAZINE

The Sky Guide

JULY 2020

JUPITER REIGNS

Mighty Jupiter reaches opposition on 14 July, a week ahead of Saturn

SUBSCRIBE
Discover the best stargazing each month

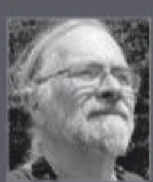
PETE LAWRENCE

SHOOTING STARS

Observe the peak of the Southern Delta Aquariids

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 50

Also on view this month...

✦ The noctilucent cloud season continues
✦ Jupiter and Pluto appear together
✦ Can you spot the Ring Nebula's central star?

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

JULY HIGHLIGHTS Your guide to the night sky this month

All month

Noctilucent cloud (NLC) season continues through July, coming to an end at the start of August.

Wednesday 1

Mag. –2.6 Jupiter sits 42 arcseconds north of mag. +14.3 Pluto this evening. This magnitude difference means that Jupiter appears 5.8 million times brighter than Pluto!

Sunday 5

A penumbral lunar eclipse begins at 04:07 BST (03:07 UT) today but is unlikely to be observable as the Moon will be setting below the southwest horizon.

◀ Thursday 9

As Jupiter approaches opposition, the shadows cast on its atmosphere by its four Galilean moons appear closer to the moons themselves. At 02:15 BST (01:15 UT) Io and its shadow sit together centrally on Jupiter.

Friday 10

This morning it's the turn of Europa and its shadow to appear almost together. Both appear centrally on Jupiter's disc around 02:30 BST (01:30 UT).

Saturday 11

As Venus rises this morning it will appear just 1° from Aldebaran (Alpha (α) Tauri).

Jupiter appears to gain an extra moon in the form of TYC6311-253-1. The star lies 1.5 arcminutes east of Jupiter's centre at 23:50 BST (22:50 UT).

Sunday 12

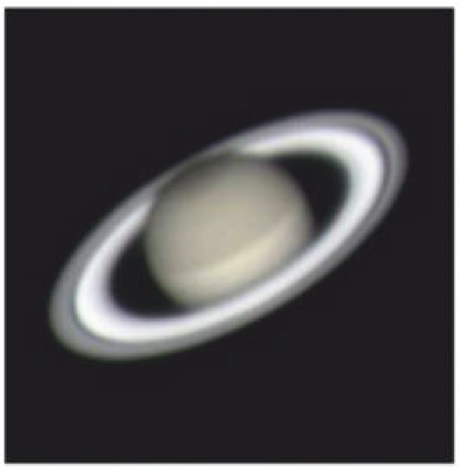
This morning's 59%-lit waning gibbous Moon lies 3° from mag. –0.7 Mars.

Sunday 19

This morning mag. +0.9 Mercury gets a visit from a rather slender 2%-lit waning crescent Moon, appearing 3° north (above and left as seen from the UK) of the planet at 04:15 BST (03:15 UT).

Monday 20 ▶

Hot on the heels of iJupiter, Saturn reaches opposition today. Watch out for the Seeliger effect, when the planet's rings appear brighter than expected at opposition.



Saturday 25

Callisto transits Jupiter from 22:55 BST (21:55 UT), appearing centrally on Jupiter's disc at 00:45 BST on 26 July, (23:45 UT, 25 July), and finishing at 03:00 BST (02:00 UT) on the 26th. Callisto's shadow chases the Moon from 01:40 BST (00:40 UT) on 26 July.

PETE LAWRENCE X 6

Friday 3

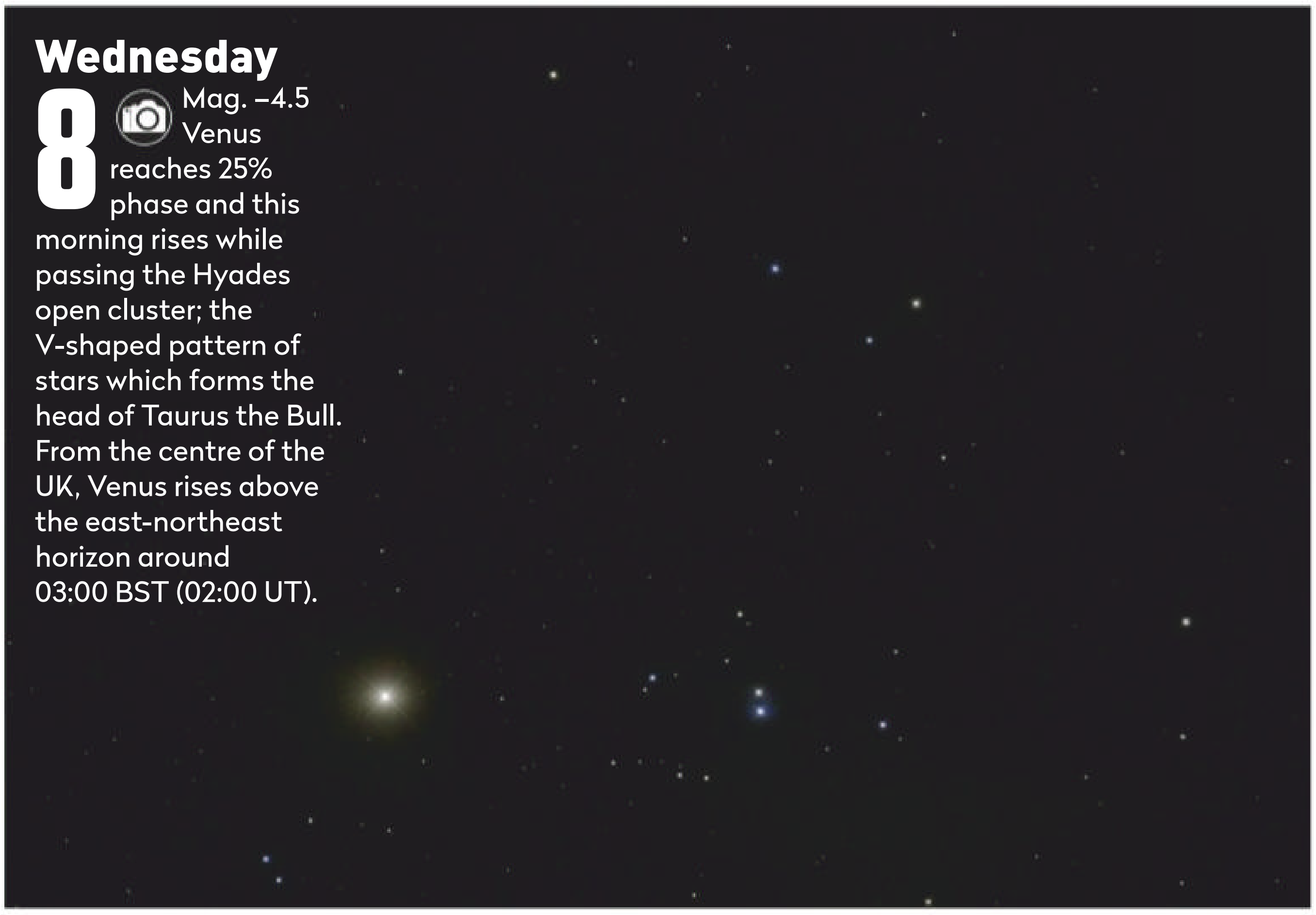
After its evening appearance during the first half of 2020, the planet Venus is now a brilliant beacon in the morning sky. Shining at mag. –4.5, through a telescope Venus appears as a 20%-illuminated crescent today.

◀ Saturday 4

Earth reaches aphelion today at 12:34 BST (11:34 UT), the position where our planet is at its greatest distance from the Sun for the year, at 152,095,295km. The Sun also shows the smallest apparent diameter at this time.

Wednesday 8

Mag. –4.5 Venus reaches 25% phase and this morning rises while passing the Hyades open cluster; the V-shaped pattern of stars which forms the head of Taurus the Bull. From the centre of the UK, Venus rises above the east-northeast horizon around 03:00 BST (02:00 UT).



Monday 13

Minor planet 2 Pallas reaches opposition in the constellation of Vulpecula the Fox. At mag. +9.6, it's within easy reach of a small scope.

Tuesday 14

Jupiter reaches opposition, a time when it appears at its biggest and brightest from Earth.

Friday 17

This morning's 14%-lit waning crescent Moon lies 2.8° from mag. –4.3 Venus with orange star Aldebaran close by. Watch them from 03:00 BST (02:00 UT) low above the east-northeast horizon.

Thursday 30

The Southern Delta-Aquariid meteor shower reaches its peak with a ZHR of 18 meteors per hour.

Family stargazing

Jupiter has a total of 79 officially recognised moons. Only four can be seen using a telescope as they perform their orbital dance around Jupiter. If you have a scope, point it at Jupiter and using a low to medium power eyepiece, get your young observers to sketch what they see. Mark the positions of the Moons as dots either side of the planet. Sometimes a moon may be behind (occulted) or in front of (transiting) Jupiter and won't be visible. Use our graphic on page 45 to help identify them. Remember, your scope may show a view which is upside down, ie, with south up. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

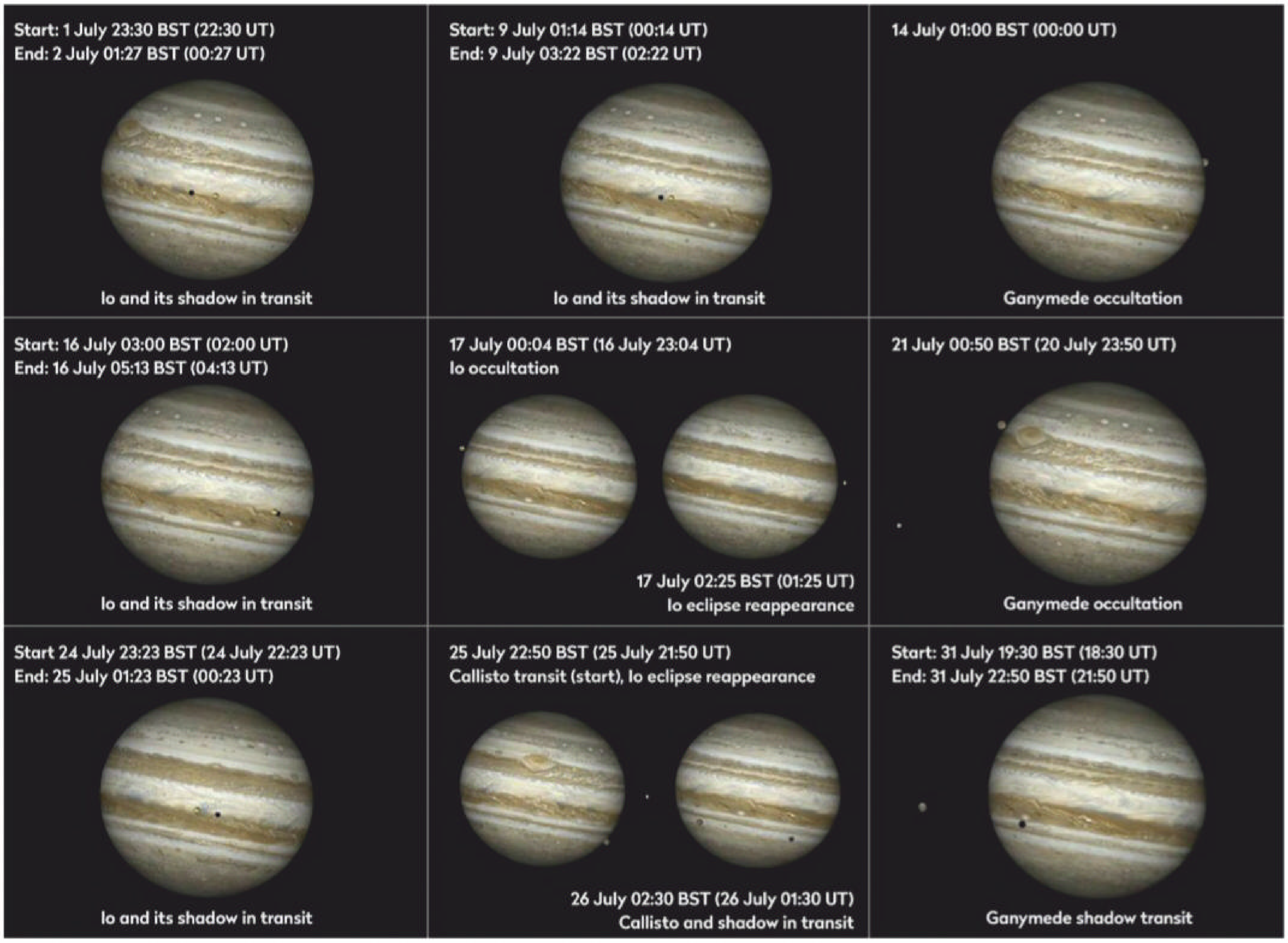
Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE The three top sights to observe or image this month



▲ **In a month that sees Jupiter reaching opposition (on 14 July), there's a wide selection of moon events (note that these views are south-up)**

The moons of JUPITER

BEST TIME TO SEE: See diagram above

Jupiter is at opposition on 14 July, a time when the planet will be in the opposite part of the sky to the Sun. At opposition the distance between Earth and Jupiter will be at a minimum for the current period of observation. This means Jupiter's disc will appear slightly larger and brighter than at other times.

Another consequence of this alignment is that the four Galilean moons and their shadows appear to align. When the Sun, Earth and Jupiter are in a direct line, the shadows appear to line up behind their respective moons. A perfect line up requires the difference between Jupiter's ecliptic longitude and that of the Sun to be 180°. However, typically the ecliptic latitude will not be 0°, which is the ecliptic latitude of the Sun. This means the moon shadows tend to appear either above or below their respective moons. In addition, Jupiter and the Sun only maintain their 180° opposition position for a short period of time. Catch a moon and its shadow passing across Jupiter's face on the day before or after opposition and it's quite evident that the alignment isn't perfect.

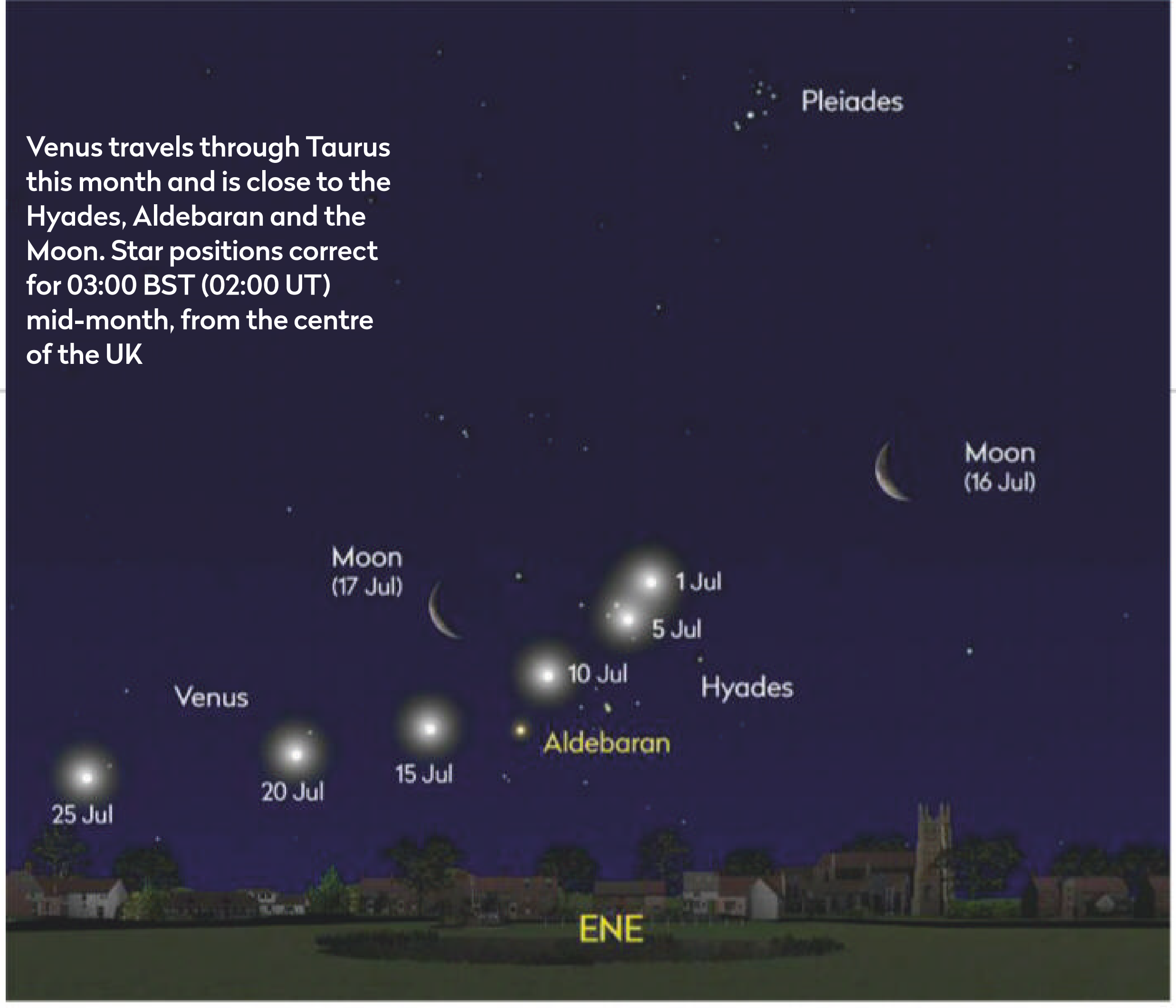
There are other effects too. Jupiter itself casts a large shadow behind it. Obviously this is hidden by the darkness of space, but it is revealed by the Galilean moons. As they head behind the planet they pass into the shadow for an eclipse event. During periods away from opposition the outer moons can pass into the shadow and out of it again on the same side of Jupiter: visually they effectively disappear then reappear again.

As we get closer to opposition so Jupiter's shadow becomes more aligned with the planet. The moons disappear as they enter it and then remain hidden as they pass behind Jupiter's disc. They then reappear from behind the planet's bright eastern limb. After opposition the reverse takes place. The moons disappear behind the planet's bright western limb then emerge still within Jupiter's shadow, which is now present on the eastern side of the planet. The moons appear to magically pop into view as they leave the shadow.

At opposition, Jupiter's shadow lines up with the planet's disc as seen from Earth, so for a short time the moons disappear behind the planet's western limb and reappear behind the eastern limb.

There are a lot of moon events taking place this month and we've indicated several interesting ones in the main graphic (above). Watching the Galilean moons dance around gas giant Jupiter is fascinating and can be done quite easily with a small telescope.

ALL PICTURES: PETE LAWRENCE



Venus travels through Taurus this month and is close to the Hyades, Aldebaran and the Moon. Star positions correct for 03:00 BST (02:00 UT) mid-month, from the centre of the UK

Venus in the Hyades

BEST TIME TO SEE: All month, with the morning of 12 July for a close conjunction with Aldebaran and 17 July for a photo opportunity with the Moon

Venus has been re-emerging from its alignment with the Sun on 3 June, but unlike its evening appearance at the start of 2020, at the moment its altitude is poor before sunrise. In order to spot it, you'll need a flat east-northeast horizon.

Back in April, it passed in front of the Pleiades open cluster in Taurus; and during the first half of this month, the planet will be near mag. +0.8 Aldebaran, passing through Taurus's other famous cluster, the Hyades. This won't be as dramatic as the Pleiades crossing in April, however, because the Hyades will be low and set against the dawn twilight.

Binoculars may show some of the brighter cluster stars as the Hyades rises above the horizon, and this could be an interesting challenge for a camera setup. Aldebaran should definitely be bright enough to be seen; Venus will be closest to it, 57 arcminutes away, on the morning of 12 July.

On the morning of 17 July, Venus, Aldebaran, the Hyades and a 13%-lit waning crescent Moon will appear together low in the east-northeast from around 03:00 BST (02:00 UT). If you're planning to photograph the scene, don't forget that the Pleiades are also close by, located 14° northwest of Aldebaran. Given a good flat horizon, it should be possible to frame them all using a 60mm or shorter lens fitted to a non-full frame camera, or if using a full frame camera, a 100mm or shorter lens.

By month's end, most of Taurus will be visible in relative darkness higher above the horizon but Venus will be further from the Hyades. On 31 July it will be positioned 2.5° southwest of mag. +3.0 Zeta (ζ) Tauri.

Noctilucent clouds

BEST TIME TO SEE: All month

The month of July represents the second half of the UK's noctilucent cloud (NLC) season. This normally runs from late May to early August with the best chance of seeing a display during June and July.

NLCs are the highest clouds in the atmosphere, occurring in a layer 82km up in the mesosphere. At this height they are still illuminated when the Sun is between 6° and 16° below the horizon. Despite it being night for us on the ground, NLCs appear to shine against the deep twilight sky in which they sit, hence the name noctilucent which means night-shining.

If present they will normally appear low above the northwest horizon 90–120 minutes after sunset or a similar time before sunrise above the northeast horizon. An extensive display may first appear in the northwest, tracking through north before it disappears in the northeast before dawn. What's happening here is essentially the ice sheets which are NLCs reflect sunlight, tracking the position of the Sun below the northern horizon.

NLCs may vary in appearance and in terms of how extensive they appear. A typical display will appear to shine with an electric blue colour and exhibit a delicate, mesh-like structure. If any normal clouds are in same area, they will typically appear dark against the higher, sunlit NLCs.

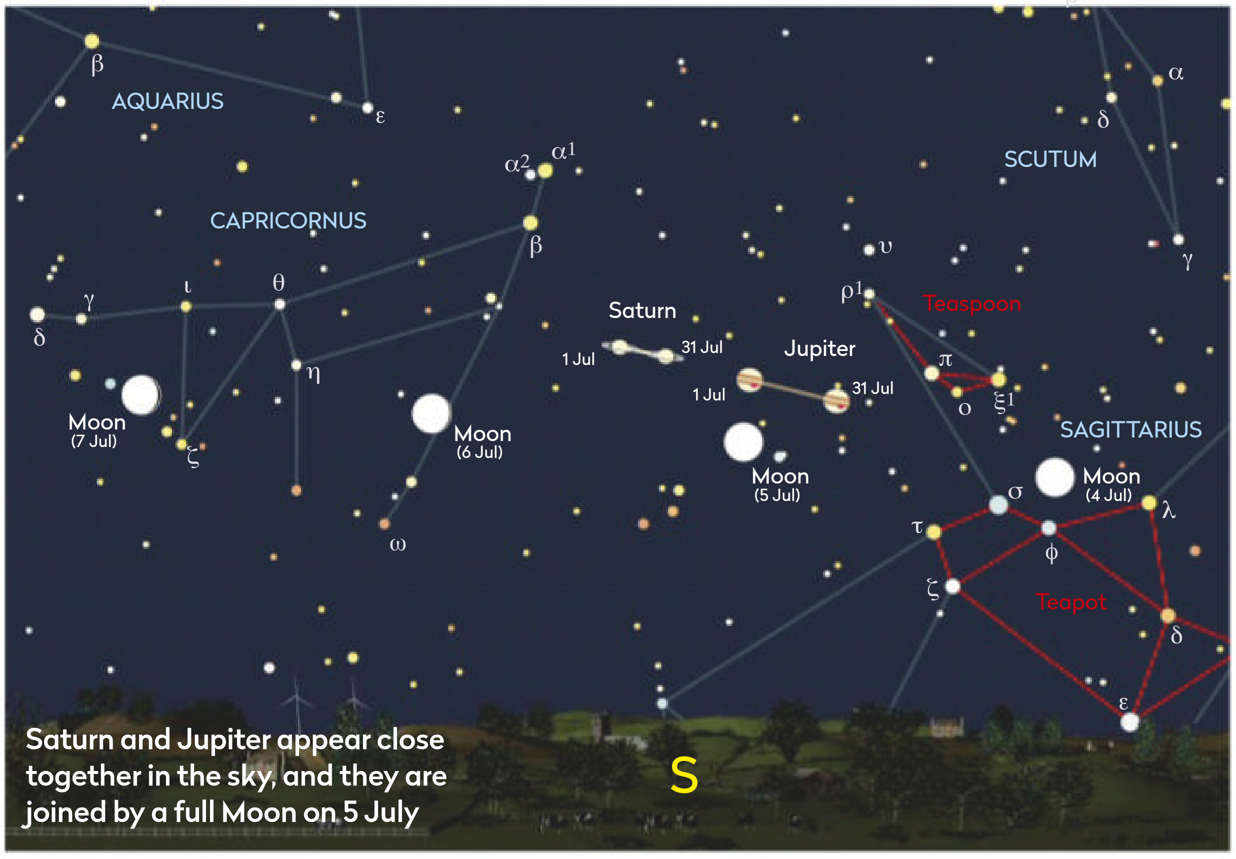
High profile: noctilucent clouds typically appear 90-120 minutes after sunset or a similar time before sunrise

THE PLANETS Our celestial neighbourhood in July

PICK OF THE MONTH

Saturn

Best time to see: 20 July, From 00:00 BST (23:00 UT)
Altitude: 16°
Location: Sagittarius
Direction: South
Features: Rings, atmospheric belts, occasional storms, moons
Recommended equipment: 150mm or larger

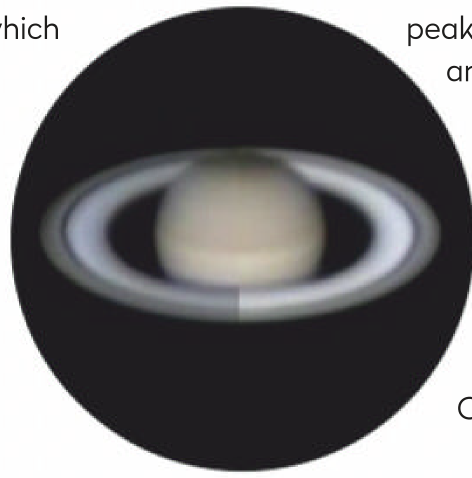


Saturn and Jupiter appear close together in the sky, and they are joined by a full Moon on 5 July

The planet Saturn reaches opposition on 20 July. Opposition is the term used to describe when a planet lies on the opposite side of the sky to the Sun. In this position we are at the closest to that planet and consequently it appears bigger and brighter than at other times.

The more distant a planet is from the Sun and therefore Earth, the smaller these effects become. For example, we're going to see major changes in the appearance of Mars as we head through to its opposition on 13 October. Jupiter too will be at its brightest and largest through the eyepiece on 14 July, but the changes are less impressive than those which will appear for Mars. And the progression continues through to Saturn with its brightness and increase in apparent size being fractionally less impressive than that which occurs with Jupiter.

Having said this, Saturn still has a trick up its sleeve in the form of the Seeliger effect. As the planet approaches opposition, the myriad particles which make up its ring system line up so that from Earth the shadows they cast on particles further back are hidden from view. The net effect is a brightening of the rings. This effect can normally be seen a few days before opposition, reaching a peak brightness at opposition and then fading off in the days after.



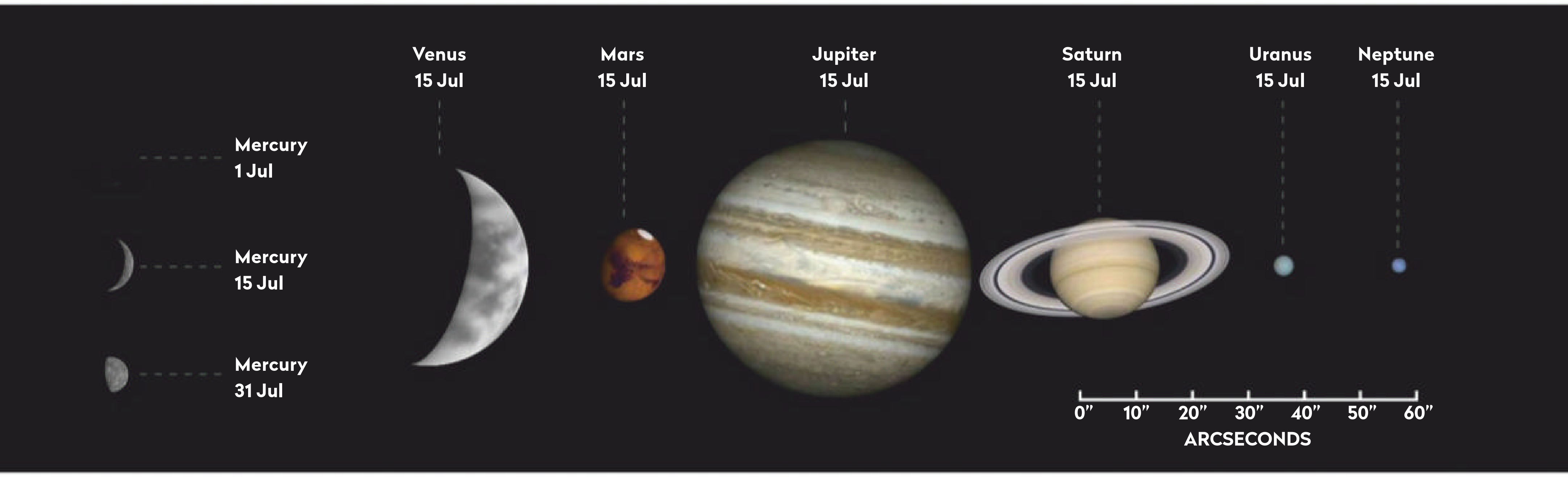
▲ Saturn's rings can appear to brighten significantly at opposition

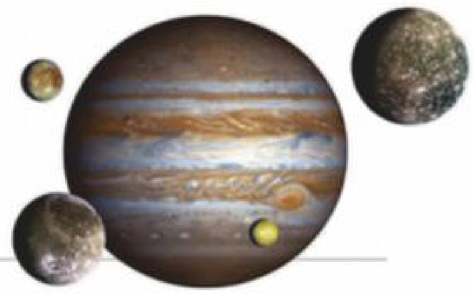
Saturn and Jupiter reaching opposition within a week of each other occurs as a consequence of both appearing close in the sky. On 20 July Saturn appears 7.1° east of Jupiter. At opposition, Saturn's brightness will be mag. +0.4. A full Moon – the Moon at opposition – lies near to both planets on the evening of 5 July and into the following morning.

PETE LAWRENCE X 3

The planets in July

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 31 July, 1 hour before sunrise
Altitude: 4° (very low)
Location: Gemini
Direction: Northeast

Mercury reaches inferior conjunction on 1 July and then returns to morning skies. It's poorly placed in July's first half but improves from the 16th, as it brightens and appears higher before sunrise. On 16 July it rises over the northeast horizon an hour before sunrise. Greatest western elongation (20.1°) occurs on the 22nd.

Venus

Best time to see: 31 July, 04:00 BST (03:00 UT)
Altitude: 14°
Location: Taurus
Direction: East-northeast

Morning planet Venus shines at mag. –4.3 at July's start, with a scope showing it as an 18%-lit crescent, 42 arcseconds across. On 12 July, mag. –4.4 Venus appears less than a degree from mag. +0.8 Aldebaran. Venus is 28%-lit and 36 arcseconds across on this date. A waning crescent Moon sits 2.6° from Venus on 17 July, both visible close to the Hyades at around 03:00 BST (02:00 UT).

At the month's end, Venus rises three hours before sunrise, shining at mag. –4.3.

Mars

Best time to see: 31 July, 04:00 BST (03:00 UT)
Altitude: 35°
Location: Pisces
Direction: Southeast

Mars improves this month. On 1 July it hovers low above the east-southeast horizon as the sky starts to brighten. Visually it shines at mag. –0.5 and through the eyepiece its apparent size is 11 arcseconds.

As Mars rises around 1am on 12 July, it shines at mag. –0.7 and appears 3° from a waning gibbous Moon. On this date Mars attains a higher altitude in darker skies, being over 20° up by 03:00 BST (02:00 UT).

At July's end, Mars shines at mag. –1.1 and will look impressive as it reaches an altitude of 35°. On 31 July, Mars has a 14 arcsecond disc 84%-lit when viewed through a scope.

Jupiter

Best time to see: 14 July, 01:00 BST (00:00 UT)
Altitude: 15°
Location: Sagittarius
Direction: South

Jupiter reaches opposition on 14 July, appearing at its brightest and largest in 2020. At mag. –2.6 it will be impressive visually, but it's low and this will reduce the detail through a scope. A telescope view will still show the main atmospheric belts and four largest moons. The full Moon on 5/6 July lies close to Jupiter and Saturn.

Uranus

Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 23°
Location: Aries
Direction: East

A morning planet shining at mag. +5.8, Uranus is able to reach an altitude of 30° in darkness at July's end.

Neptune

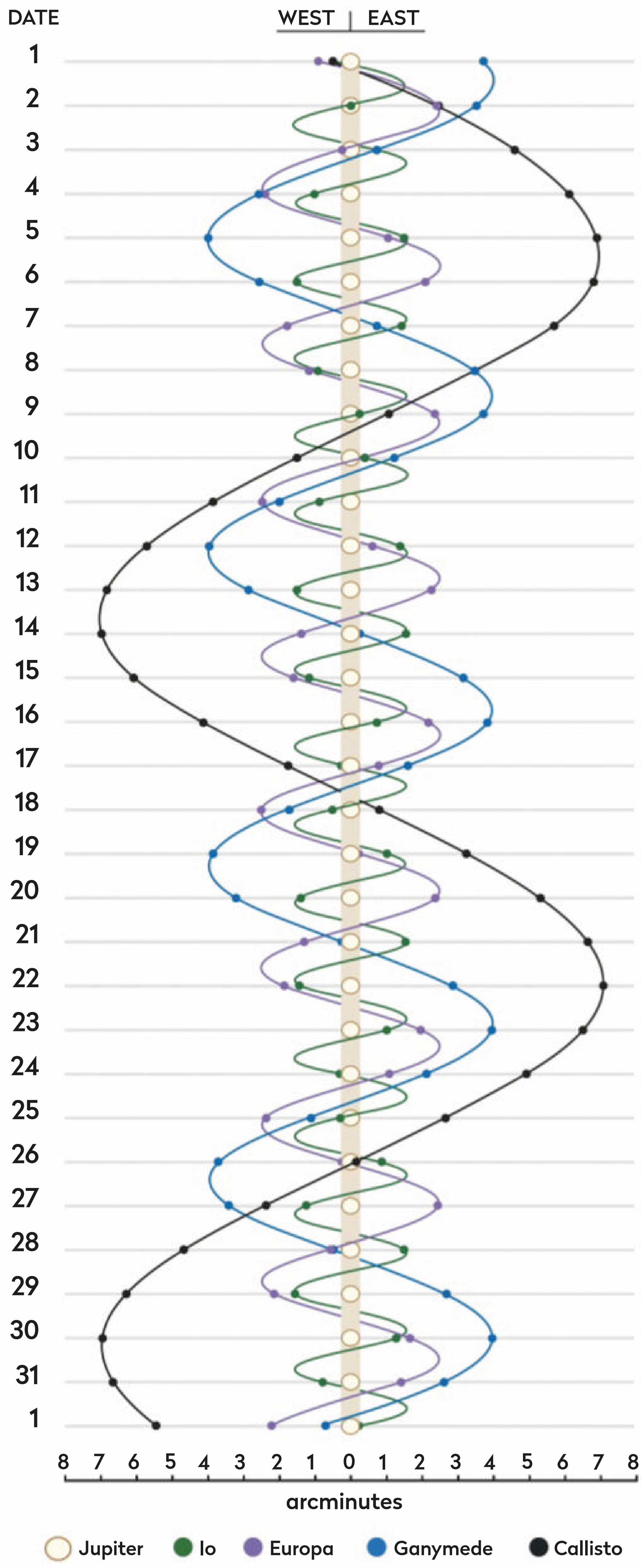
Best time to see: 31 July, 02:30 BST (01:30 UT)
Altitude: 29°
Location: Aquarius
Direction: South-southeast

Morning planet Neptune almost makes it to its highest altitude due south at the month's end. Currently in Aquarius, at mag. +7.8, it requires binoculars to see.

More ONLINE
Print out observing forms for recording planetary events

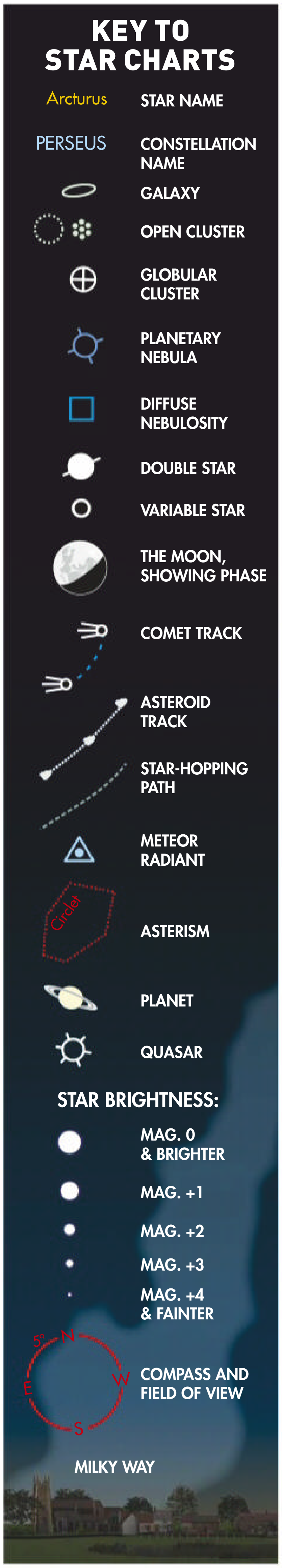
JUPITER'S MOONS: JULY

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



THE NIGHT SKY – JULY

Explore the celestial sphere with our Northern Hemisphere all-sky chart



When to use this chart

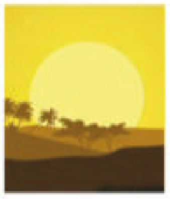
1 July at 01:00 BST
15 July at 00:00 BST
31 July at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

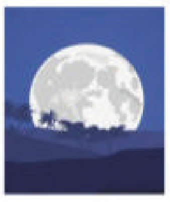
1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in July*



Date	Sunrise	Sunset
1 Jul 2020	04:46 BST	21:42 BST
11 Jul 2020	04:56 BST	21:35 BST
21 Jul 2020	05:09 BST	21:23 BST
31 Jul 2020	05:25 BST	21:07 BST

Moonrise in July*

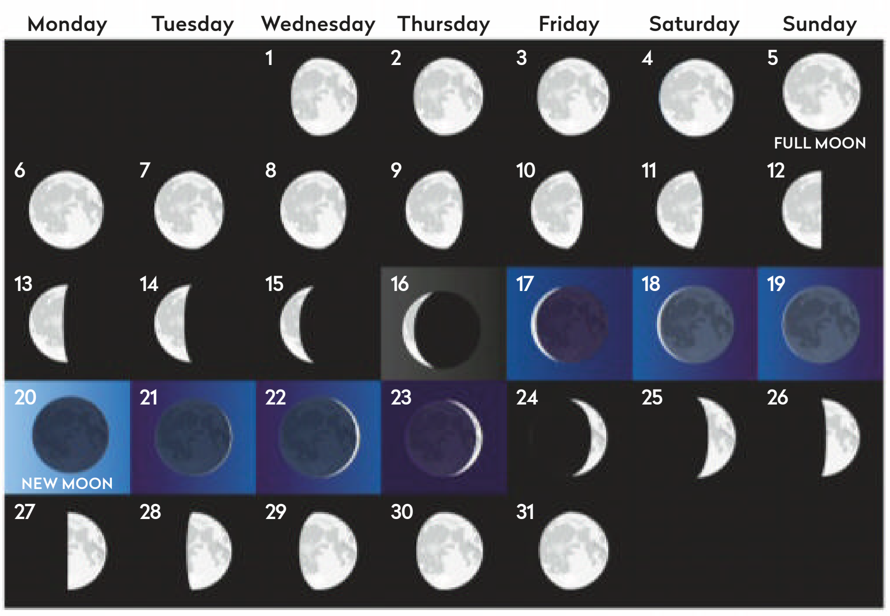


Moonrise times

1 Jul 2020, 17:35 BST	17 Jul 2020, 02:05 BST
5 Jul 2020, 22:19 BST	21 Jul 2020, 05:33 BST
9 Jul 2020, --:-- BST	25 Jul 2020, 11:08 BST
13 Jul 2020, 00:51 BST	29 Jul 2020, 16:44 BST

*Times correct for the centre of the UK

Lunar phases in July



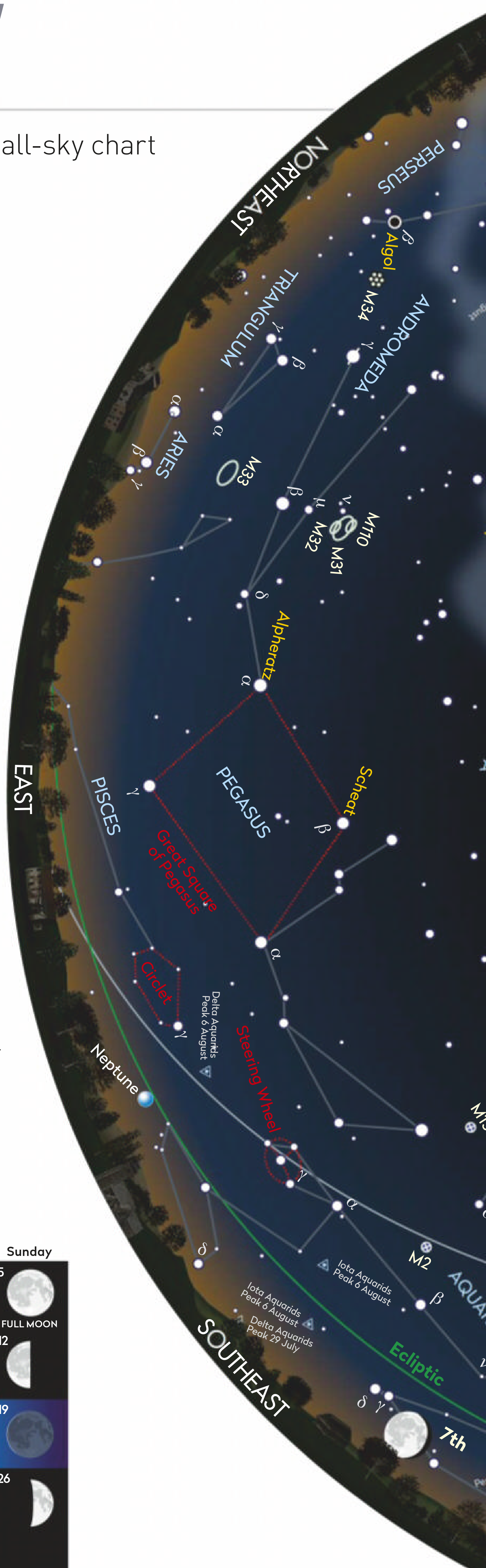


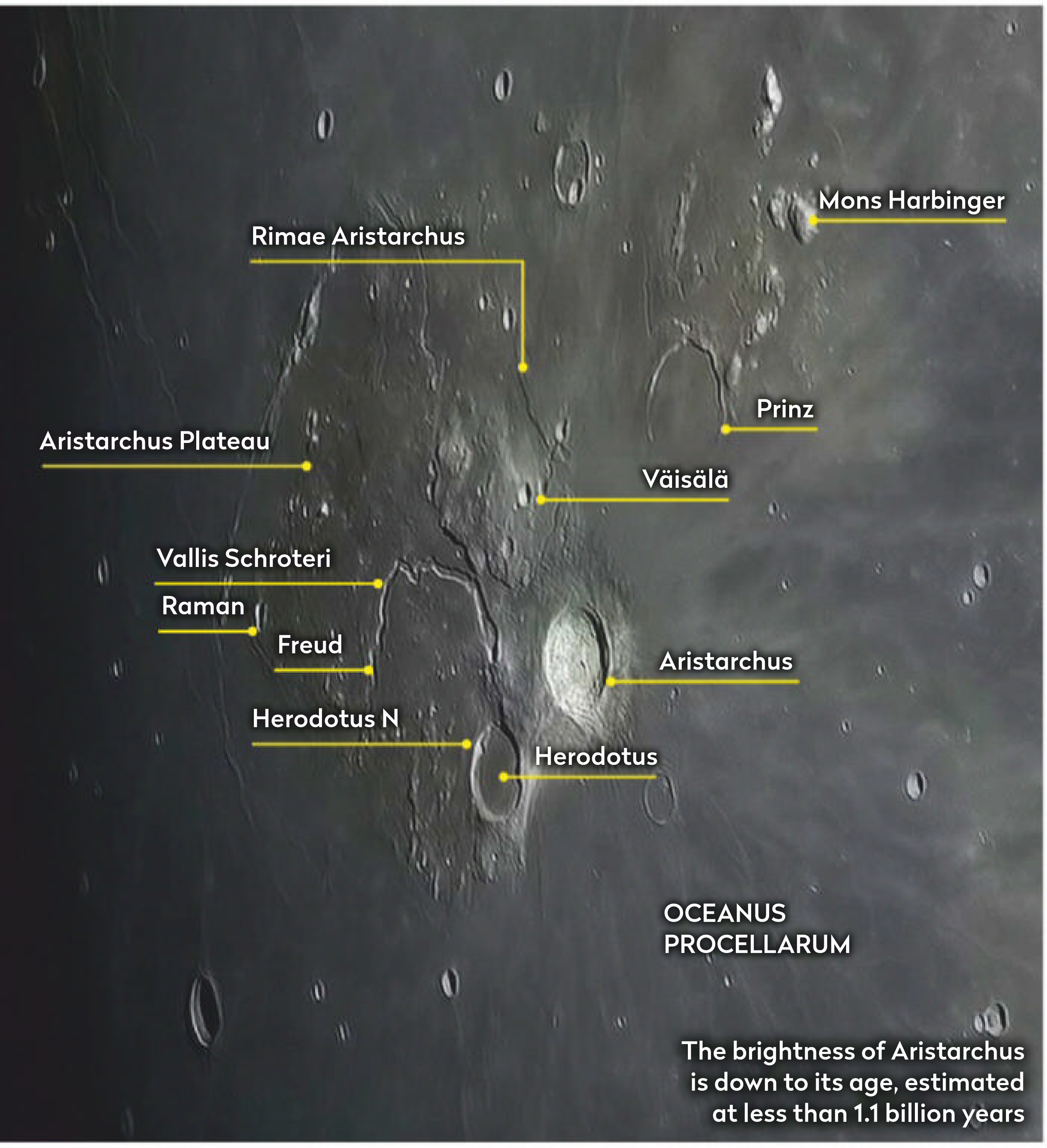
CHART: PETE LAWRENCE

MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

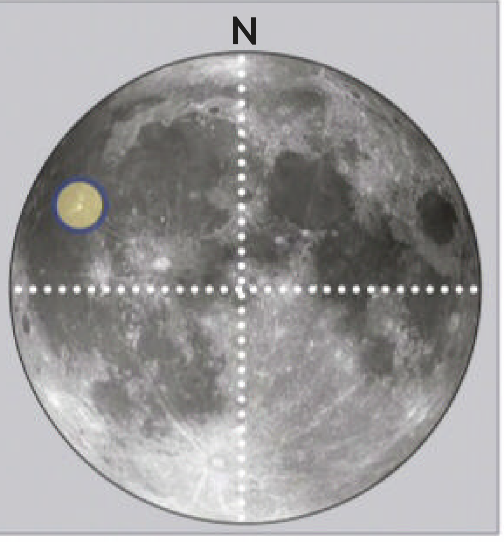
MOONWATCH July's top lunar feature to observe



The brightness of Aristarchus is down to its age, estimated at less than 1.1 billion years

Aristarchus Plateau

Type: Lunar plateau
Size: 250km
Longitude/latitude: 52.4˚ W, 25.8˚ N
Age: 3.8 billion years
Best time to see: Five days after first quarter (1–3 & 31 July) and three days after last quarter (16–17 July)
Minimum equipment: 50mm refractor



Aristarchus is a bright, 40km diameter crater best seen near to the fuller phases of the Moon. It sits in the **Oceanus Procellarum**, in a feature-rich environment isolated within Procellarum's lava. Aristarchus's brightness is dramatic and can cause issues when attempting to image the inner parts of the crater: it's tricky to maintain a good exposure level on surrounding areas without over-exposing its interior.

Aristarchus's brightness is due to its youthful age. Estimated to be less than 1.1 billion years old, the ejecta material hasn't had time to be faded by solar wind 'weathering'. The crater has well-defined ramparts rising 600m above the surrounding area, leading up to a sharp rim edge. Inside there are many terraces which lead down to a flat floor with a central mountain. The crater is 3.2km deep.

PETE LAWRENCE X 3

Step back from the crater to take in the diamond-shaped Aristarchus Plateau

Stepping back from the crater itself allows you to take in the surroundings and the diamond-shaped region known as the **Aristarchus Plateau**. Aristarchus occupies the eastern corner of the diamond. The plateau has a brown hue compared to its surroundings and this is something which is interesting to bring out when imaging the Moon with a colour camera.

Southwest of Aristarchus by 65km (centre-to-centre) lies 35km **Herodotus** which, despite having a similar size to Aristrachus, couldn't be more different in general appearance. Herodotus has a more typical lunar darkness to it. It is 1.3km deep and has a flat floor with only one 1.3km craterlet visible in typical amateur scopes. Herodotus's rim is thin and worn, interrupted in the northwest by 4km **Herodotus N**. Herodotus is a much older feature than Aristarchus with an age somewhere between 3.2–3.8 billion years.

A number of smaller craters occupy the raised plateau such as 12km **Raman** to the west, 8km **Väisälä** to the east and 3km **Freud** which sits almost in the centre. A significant feature on the plateau is **Vallis Schröteri**. This is a fascinating valley which starts thin in the west, arches north getting thicker as it goes and then curves southeast to end just north of the mid-point between Herodotus and Aristarchus. The valley widens at its end-point in the east, into a feature informally called the Cobra Head, although it looks more like a python than a cobra. A rille passes down the centre of the head, which is a good test for a high-resolution imaging setup.

Visually, it's probably easier to follow Vallis Schröteri from the 10km-wide Cobra Head. Heading north it immediately narrows to just 6km wide. About 30km north of the snake's 'nose' the valley bends towards the northwest for a further 30km. At the end of this run, it then narrows to just 4km across. The valley then meanders for around 25km as it heads west before taking a sharp turn southwest. This is where things get tricky because over the course of its remaining 90km, it narrows to a width which will be too thin to follow with amateur equipment. As an exercise, try to see just how far you can follow it. Further cracks north of Aristarchus are known as **Rimae Aristarchus**.

COMETS AND ASTEROIDS

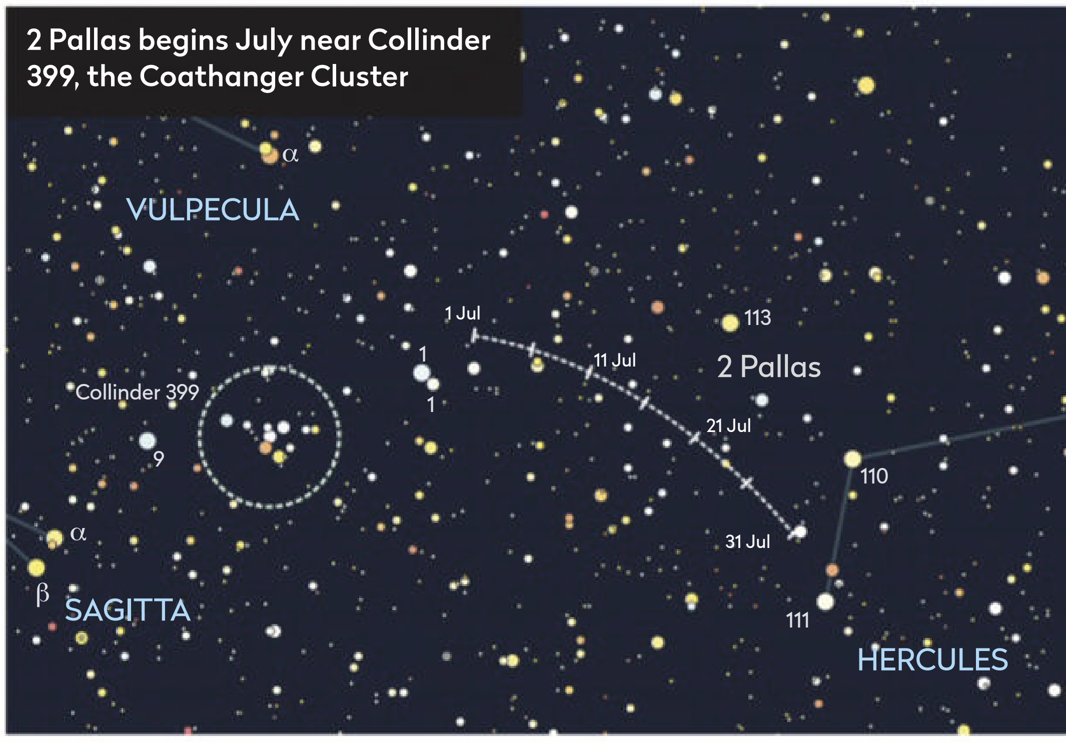
Asteroid 2 Pallas reaches opposition in Vulpecula on 13 July

Asteroid 2 Pallas reaches opposition in Vulpecula on 13 July when it will appear at mag. +9.6. Pallas starts the month just over a degree northwest of the line-of-sight star pairing formed from mag. +4.8, 1 Vulpeculae and mag. +5.7, 1 Sagittae. If nothing else, Pallas remains steady in brightness, staying at mag. +9.6 all month long. Its apparent motion against the background stars has it tracking west, arcing more and more southwest as the month progresses. As it goes, it clips the northwest corner of Sagitta before finally ending up in Hercules, close to mag. +5.9 TYC 1592-988-1 at the end of July. Its starting location puts it not too far from the asterism Collinder 399, which is also known as Brocchi's Cluster or more familiarly as the Coathanger Cluster due to the shape it forms.

As suggested by its prefix number, 2 Pallas was the second minor planet discovered. It was found by the German astronomer Heinrich Olbers on 28 March 1802. Olbers is probably best known for the Olbers' paradox, which questions why the sky is dark if the Universe is truly infinite. Pallas's discovery came relatively soon after the discovery of 1 Ceres on 1 January 1801 by Giuseppe Piazzi.

Pallas is a large main belt asteroid with a mean diameter of 512km. It contains an estimated 7% of the mass of the asteroid belt. It's classified as a B-type asteroid. These are carbonaceous bodies showing minor variations in spectral colour and are slightly more reflective than the more common C-type objects.

Pallas takes 4.62 years to orbit the Sun, its solar distance varying between 3.42 and 2.13 AU. Its orbit is highly inclined, tilted by 34.8° to the plane of the asteroid belt. It's the third largest body in the asteroid belt after dwarf planet Ceres and minor planet Vesta. At its brightest, Pallas can reach mag. +6.7.



2 Pallas begins July near Collinder 399, the Coathanger Cluster

STAR OF THE MONTH

Unukalhai, the brightest star in Serpens

Serpens the Serpent is unique in the sky because it's the only constellation that appears to split in two. The Serpent is being carried by Ophiuchus the Serpent Bearer, and appears both to the east of Ophiuchus as Serpens Cauda the Serpent's Tail, and to the west as Serpens Caput the Serpent's Head.

Both parts are made up of largely faint stars but Serpens Caput is easier to identify because of a distinctive zig-zag pattern of stars, the brightest of which is Unukalhai (Alpha (α) Serpentis). Visually, Unukalhai is the brightest star in Serpens and lies in a barren area of sky to the west of the body of Ophiuchus. The star is a good star-hopping aid for locating the zig-zag neck of the serpent leading north toward a less well-defined triangular head.

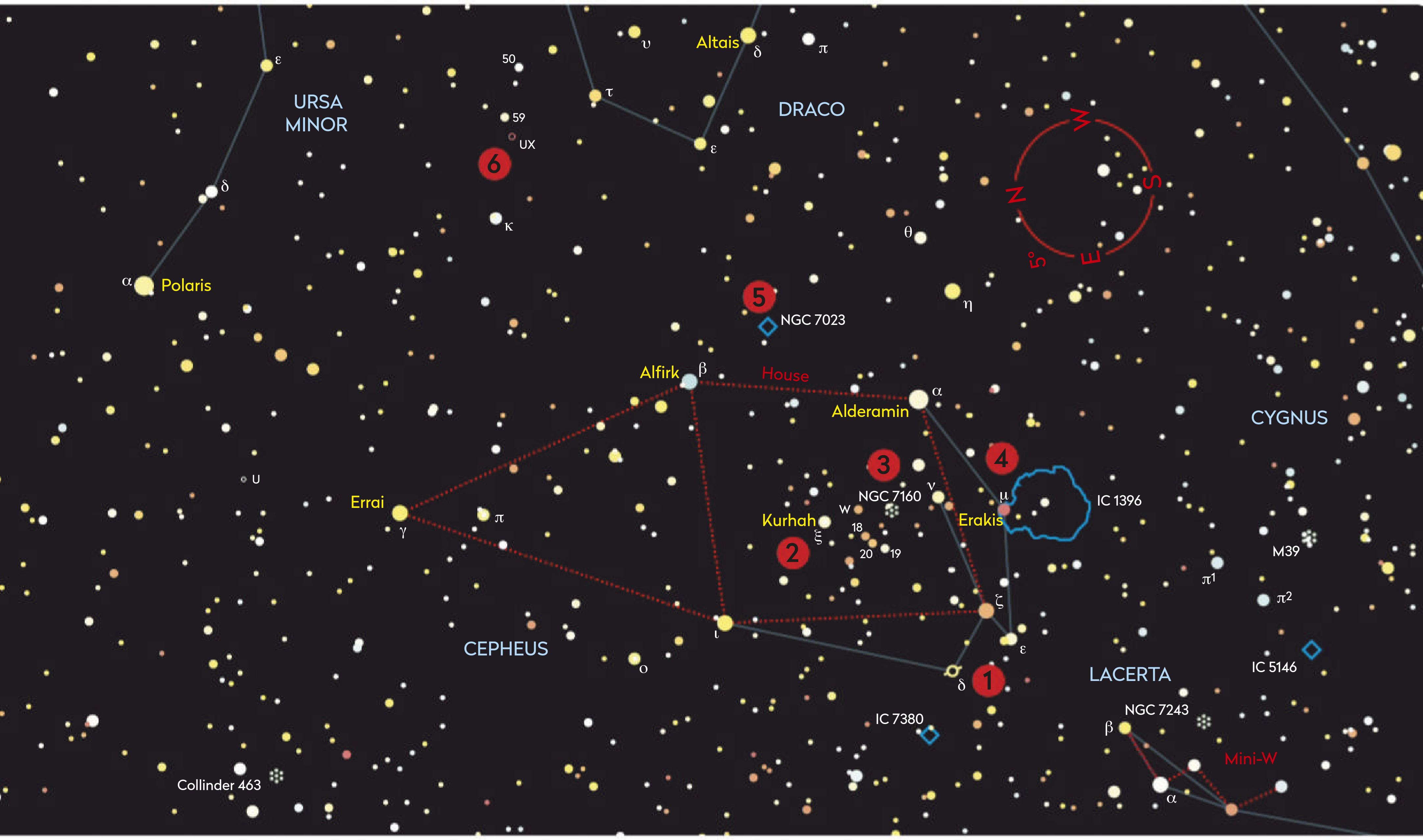
Unukalhai shines at mag. +2.6 and has a definite orange hue. Its spectrum is K2 III, the 'III' indicating it's a giant star. At its current stage of life, Unukalhai has all but exhausted its core reserve of hydrogen and is now starting to fuse helium into heavier elements such as carbon and oxygen.

Unukalhai's distance from Earth is estimated at 74 lightyears. Through a scope it has two stars that appear to lie close to it, a mag. +11.8 star 58 arcseconds away and a 13th magnitude star 2.3 arcminutes away. The name Unukalhai means 'serpent's neck', an indication as to which part of the constellation is represented in this area. Visually the star has a luminosity 38 times greater than that of the Sun but its infrared emissions are high too. When these are taken into account the output of Unukalhai is around 70 times that of our home star.

Unukalhai means 'serpent's neck'

BINOCULAR TOUR With Steve Tonkin

This month's wide-field survey begins with the eponym of Cepheid variable stars



1. Delta Cephei
10x50 Delta (δ) Cephei is an attractive double star with a deep yellow primary and a brilliant white 6th magnitude secondary, separated by 41 arcseconds. The primary gave it's name to an entire class of variable stars, the Cepheid variables, for which Henrietta Leavitt demonstrated the relationship between their period of variation and their luminosity. This relationship allowed them to be used as the first 'standard candle' for measuring the size of the Universe. ☐ **SEEN IT**

2. Kurhah star field
10x50 Kurhah (Xi (ξ) Cephei) is the brightest of a group of 5th and 6th magnitude stars that spans about 3° of sky. The group includes some red stars like 18 Cep, through to hot blue ones like 19 Cep. Allow time to appreciate the sheer variety of what is on show; the longer you look, the more you'll see. There are other groups like this nearby, so see what else you can find. ☐ **SEEN IT**

3. NGC 7160
15x70 With direct vision, NGC 7160 appears as a tiny knot of stars that could be mistaken for a globular cluster, but averted vision reveals it to be a sparse, small (about 5 arcminutes across) oval cluster. Note two brighter stars near the centre, the brighter of which is the slightly variable contact-binary star, EM Cephei. Contact binaries are binary stars that are so close together that their outer layers meet. ☐ **SEEN IT**

4. U Cephei
10x50 Continue a line from Iota (ι) Cephei through Errai (Gamma (γ) Cephei) for a further 5.5° where, midway between two mag. +5.6 stars, you'll find the eclipsing variable star, U Cephei. Its magnitude range is +6.8 to +9.2, a nine-fold variation in brightness, that makes the variability easy to detect. Its period of 2.5 days means that, if you observe an eclipse, you can repeat the observation five days later at the same time. ☐ **SEEN IT**

5. The Iris Nebula
15x70 Go back to Errai and extend a line through the sapphire blue Alfirk (Beta (β) Cephei) a further 3° to a mag. +6.8 star. Half a degree west of this star is a fainter one. Centre this star and use averted vision: surrounding the star you should begin to notice a faint glow a few arcminutes across. This is the Iris Nebula, a reflection nebula that's lit by the star. ☐ **SEEN IT**

6. UX Draconis
10x50 Use the chart to identify 59 Draconis and when you have it centred, look 0.75° back towards Cepheus where there is a very red star. This is UX Draconis, which varies irregularly by up to a magnitude (from mag. +5.9 to +7.1) with a period of around six months. However, we are visiting it for the colour: the carbon in its atmosphere makes it one of the reddest stars anywhere in the night sky. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

THE SKY GUIDE CHALLENGE

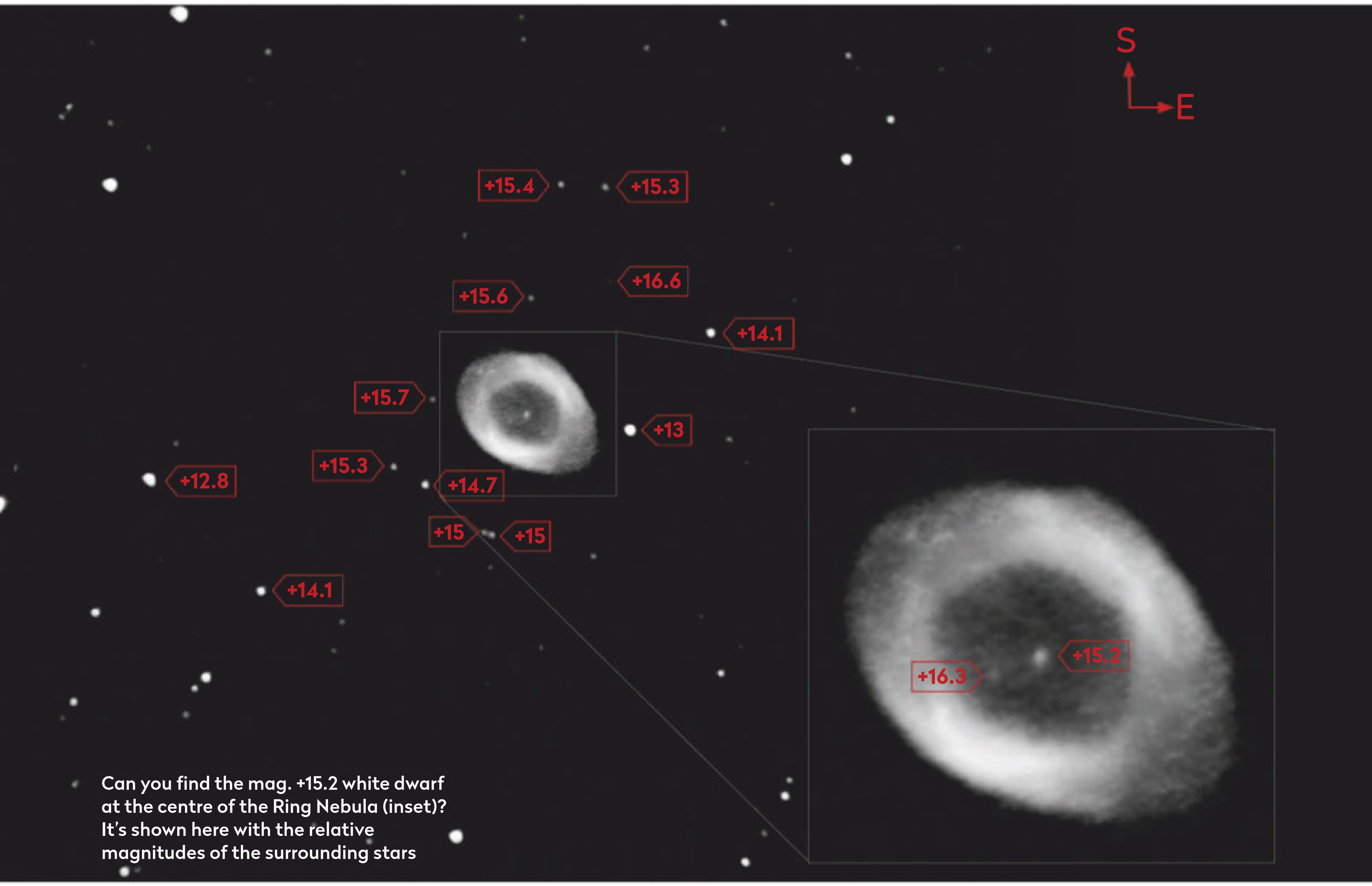
Can you observe the central white dwarf star in the Ring Nebula, M57?

The Ring Nebula, M57, is a treasured deep-sky object of the summer sky. For many it represents their first view of a planetary nebula. This is in part due to the nebula being reasonably bright – by planetary nebula standards at least – and because it's relatively easy to find. M57 represents the outer layers ejected from a star; the remaining white dwarf sits at the centre shining at mag. +15.2 (see below). The challenge is to observe M57's central star by whatever means available.

Before we try to record the central star, let's familiarise ourselves with how to find M57. This is a mag. +8.8 planetary nebula, set between the two stars at the southern end of the squashed diamond pattern forming the body of Lyra the Lyre. A lyre is a musical instrument not dissimilar to a harp: and Lyra's diamond shape represents the stringed portion of the instrument.

Your two guide stars are Sheliak (Beta (β) Lyrae) and Sulafat (Gamma (γ) Lyrae). M57 sits a fraction south of the line joining these stars, 40 per cent of the way along this line starting at Sheliak. Looking for M57 with a low power eyepiece may initially prove tricky because it's actually quite small and easily overlooked as a star. The 'trick' to locating it is to line up with the area using a wide-angle eyepiece, pick the most likely fuzzy star contender and increase the magnification. If you've chosen correctly the 'fuzzy star' should start to look a bit like a small, dim planet, the reason why these objects are called planetary nebulae. Larger apertures with higher magnifications will reveal M57's disc to be oval in shape and appear darker in the centre. Overall, this gives the appearance of a ring, explaining why M57 is called the Ring Nebula.

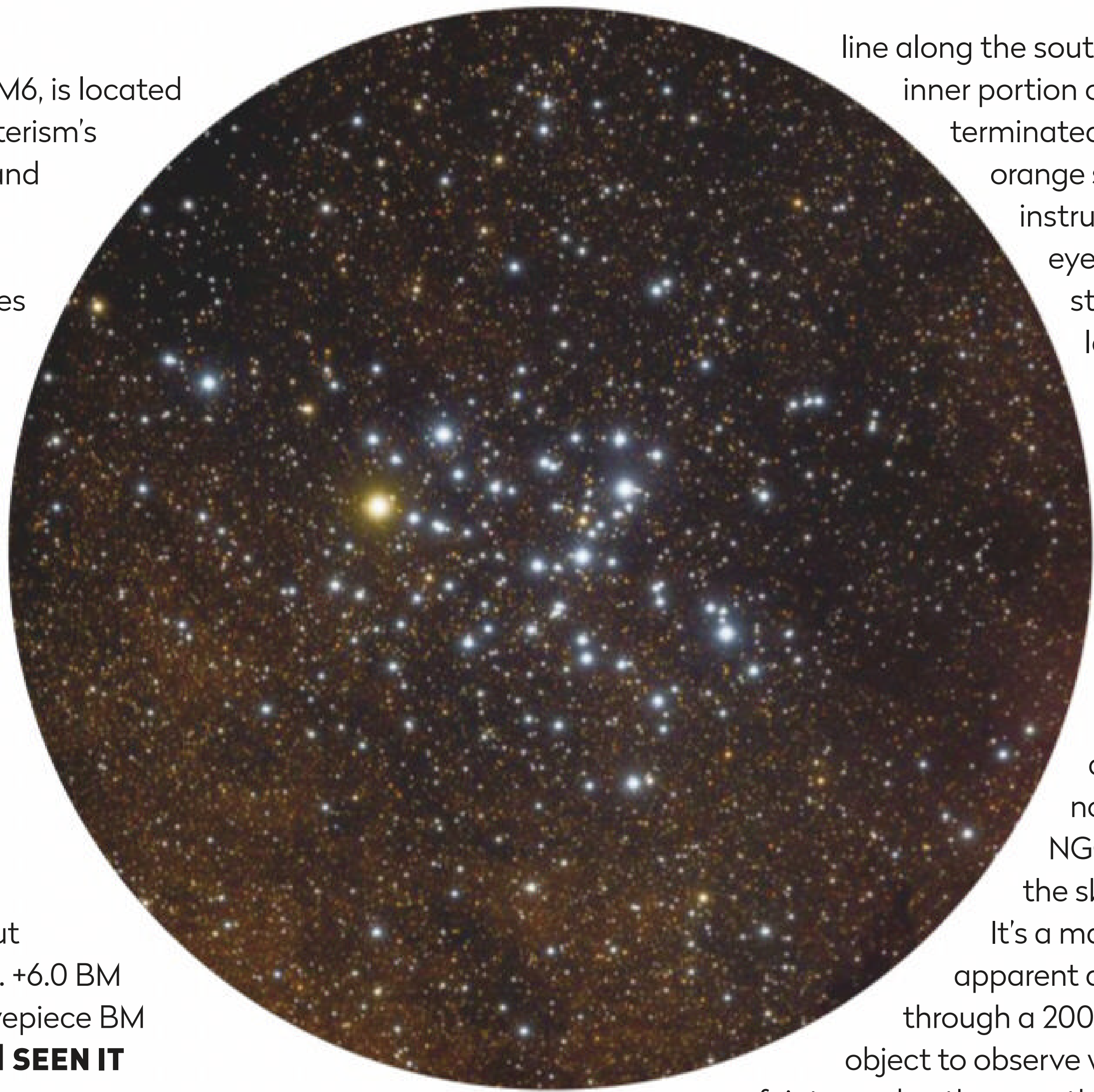
To see the central star visually, you'll ideally need a large scope, say around 400mm aperture. This is ideal territory if you have access to a large Dobsonian. If not, you might take heart in hearing that it has been reported through 300mm reflectors, 250mm Schmidt-Cassegrains and even a 200mm refractor. Seeing conditions need to be near perfect for this to happen though. Photography is perhaps a more fruitful method of recording it. Here, you'll need to use a reasonable image scale which shows M57 as a tangible ring. If you do manage to record it and have access to different sizes scopes, experiment to find the smallest instrument you can record it with. Also see how many different cameras you can catch it with – what about using a smartphone camera pointed down the eyepiece of a telescope? If you have success, please don't forget to send us your results.



Can you find the mag. +15.2 white dwarf at the centre of the Ring Nebula (inset)? It's shown here with the relative magnitudes of the surrounding stars

DEEP-SKY TOUR

We explore the celestial targets around the Butterfly Cluster, M6



▲ **Locate M6, the beautiful Butterfly Cluster, in Scorpius**

BERNHARD HUBL/CCDGUIDE.COM, CHART BY PETE LAWRENCE

1 M6

The Butterfly Cluster, M6, is located west of the Teapot asterism's spout. Identify the Teapot and extend the line of the spout – Delta (δ) to Gamma (γ) Sagittarii – about 1.8x. M6 lies 1° below the position you come to. Despite its proximity to Sagittarius, M6 lies within Scorpius. A 150mm scope shows around 40 stars in an area two-thirds the apparent size of the full Moon. The group is elongated northeast-southwest. A low power view reveals two lobe-like patterns, symmetrically arranged like the wings of a butterfly. One star shines out above the others here, mag. +6.0 BM Scorpii. With a wide-field eyepiece BM appears orange in colour. ☐ **SEEN IT**

2 NGC 6383

Head 1.2° west and 0.2° south from M6 and you'll arrive at the open cluster NGC 6383. This is dimmer than M6 at mag. +5.5 but a similar size, 20 arcminutes across. There are fewer stars here: a 150mm scope reveals around 20 appearing to spread mostly northwest of a brighter, mag. +5.7 star. In fact, this bright blue-coloured star is good at hiding the rest of the cluster. Look at it using a low-power eyepiece and the star dominates; increase magnification to 100–150x to reveal the other stars. Look out for the small arc of stars to the northwest of the brighter star, visually balanced by a straighter line running east. ☐ **SEEN IT**

3 M7

M7 is easy to find because it's big and relatively bright. Shining with an integrated magnitude of +3.3, this most southerly Messier occupies an area 90 arcminutes across. It's located 3.9° southeast of M6 and easy to find from low northern or southern latitudes, standing out well to the naked eye. From mid-northern latitudes, it never gets significantly above the southern horizon and its impact is muted. There are lots of blue stars here, some of which form a line along the southern edge of the brighter inner portion of the cluster. The line is terminated to the west by a solitary orange star of mag. +5.6. A 250mm instrument using a low power eyepiece shows around 100 stars. The brightness and large apparent size of M7, also known as Ptolemy's Cluster, comes about because it's close at 980 lightyears. ☐ **SEEN IT**

4 NGC 6453

Our next target is a globular cluster which is located half a degree to the west-northwest of the centre of M7. NGC 6453 sits in a busy part of the sky and is easy to overlook. It's a mag. +9.8 object which has an apparent diameter around 1.3° as seen through a 200mm scope. It's a difficult object to observe well, looking more like a faint smudge than anything else. A few stars may be seen in front of the core but these are foreground objects, the globular itself is unlikely to be resolved. The reason why it's troublesome is down to its distance from Earth, it being 31,300 lightyears away. ☐ **SEEN IT**

5 NGC 6528

Our next two targets are close to one another as well as being easy to find. To locate them return to the tip of the Teapot's spout as marked by the star Alnasl (Gamma (γ) Sagittarii). The first one is located 26 arcminutes north-northwest of Alnasi. Here you'll find the mag. +9.5 globular cluster NGC 6528, but chances are you'll have to work for it. This is a small object, just over 1 arcminute in apparent diameter through a 250mm scope; at low powers it's easy to overlook as a fuzzy star, but at 80x and higher it looks mottled. And this is where the fun begins because you're looking in towards the Milky Way's core and there are many stars to be seen. ☐ **SEEN IT**

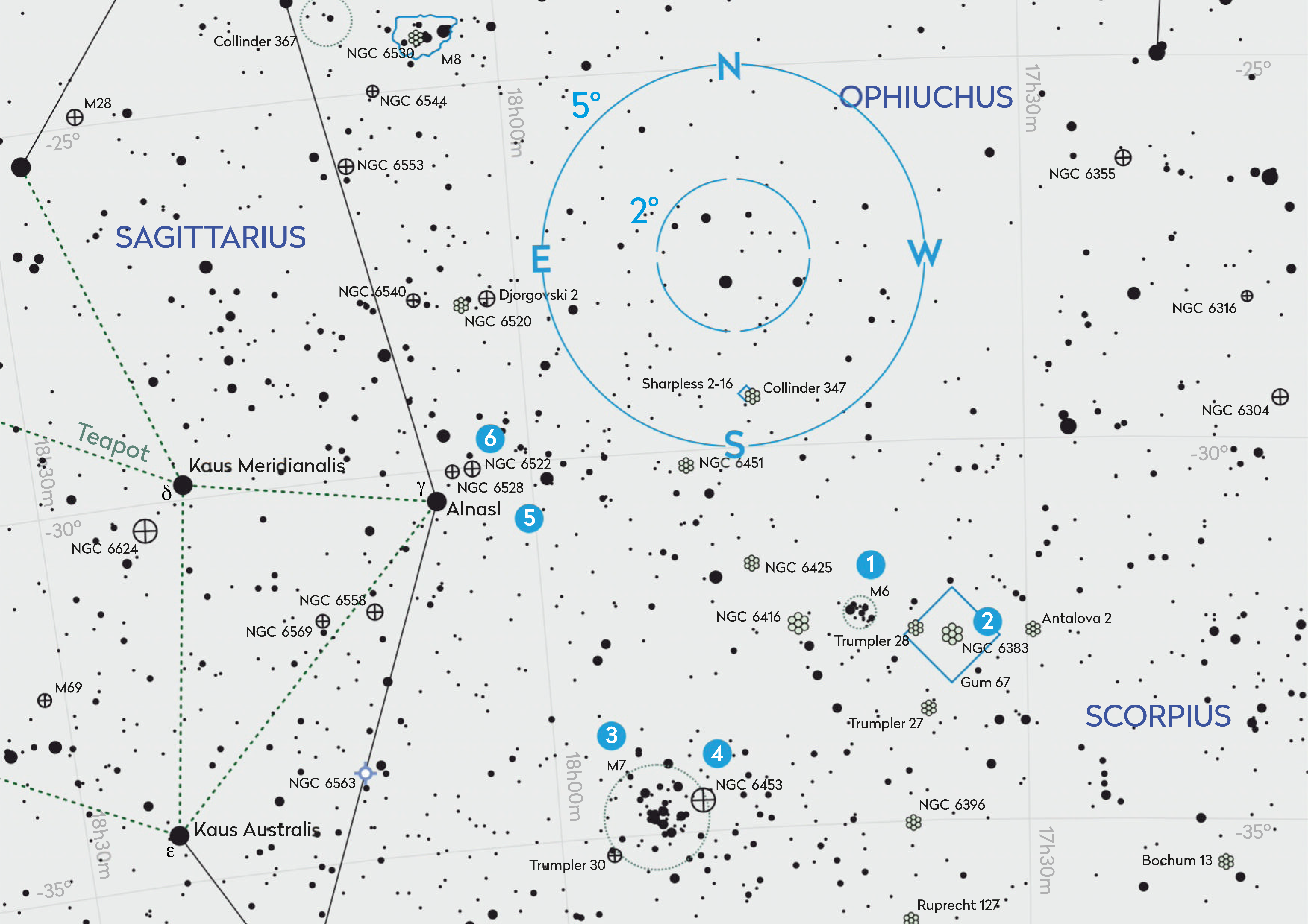
6 NGC 6522

Our last object has an integrated magnitude of +8.4 and it's also easy to locate, lying 15 arcminutes to the west of NGC 6528. A 150mm scope shows it to have a well-defined core with a faint surrounding halo perhaps as large as 2 arcminutes in diameter. A 250mm scope shows the bright core to be slightly elongated. A curious dark lane cuts across the western edge of the core, running north to south. Don't be afraid to up the power here, as NGC 6522 is 25,100 lightyears away. ☐ **SEEN IT**

This Deep-Sky Tour has been automated
ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

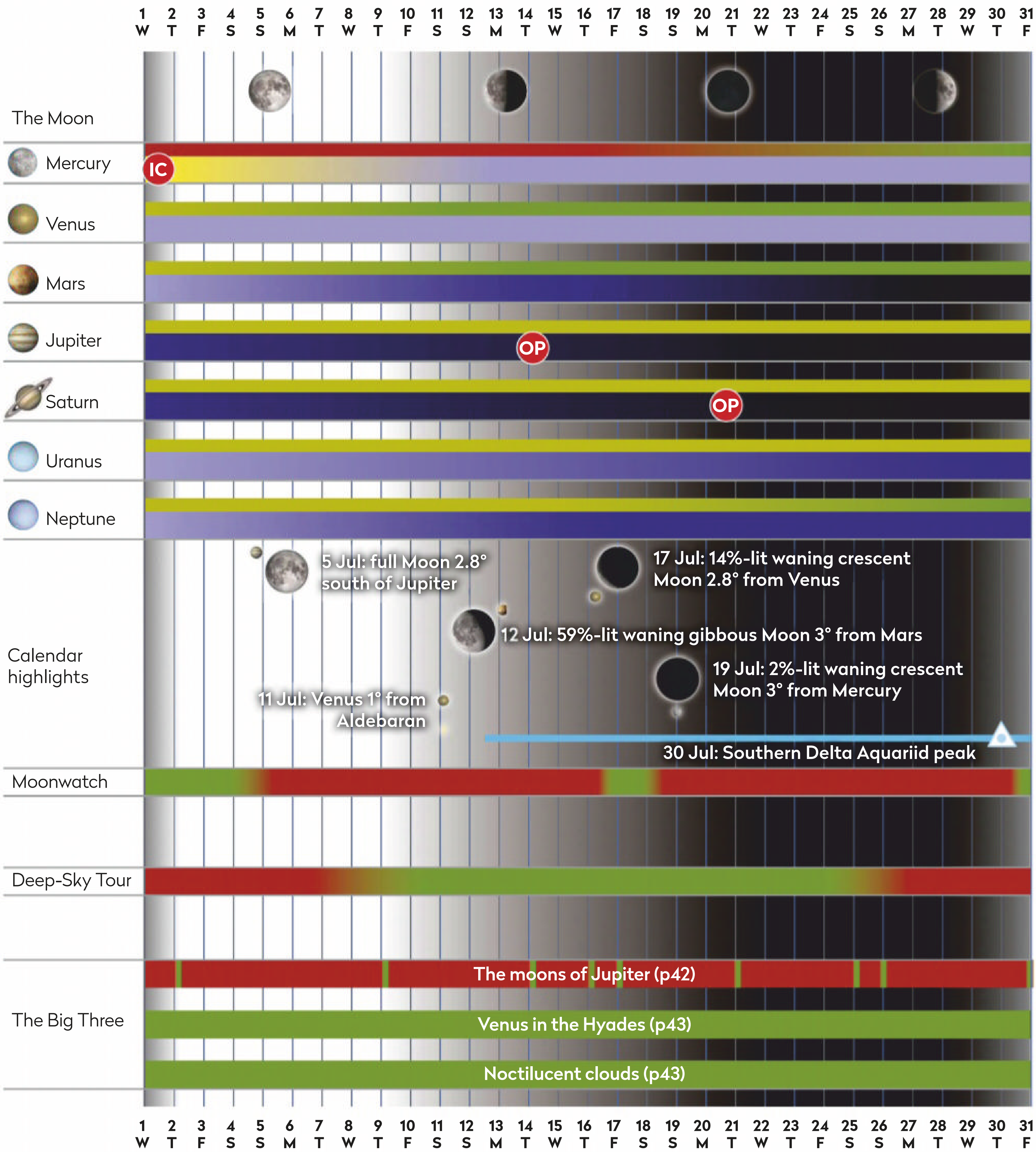
More **ONLINE**

Print out this chart and take an automated Go-To tour. See page 5 for instructions.



OPHIUCHUS
SAGITTARIUS
SCORPIUS
N
E
S
W
5°
2°
Collinder 367
NGC 6530
M8
NGC 6544
M28
NGC 6553
NGC 6540
Djorgovski 2
NGC 6520
Sharpless 2-16
Collinder 347
NGC 6355
NGC 6316
NGC 6304
Teapot
Kaus Meridianalis
δ
γ
Alnasl
NGC 6522
NGC 6528
NGC 6451
NGC 6624
NGC 6425
M6
NGC 6416
Trumpler 28
NGC 6383
Gum 67
Antalova 2
NGC 6558
NGC 6569
M69
Trumpler 27
M7
NGC 6453
NGC 6396
NGC 6563
Kaus Australis
ε
Trumpler 30
Bochum 13
Ruprecht 127
1
2
3
4
5
6
18h00m
17h30m
18h30m
-25°
-30°
-35°

AT A GLANCE How the Sky Guide events will appear in July



KEY

Observability

Optimal | Poor

Best viewed

Morning twilight | Daytime | Evening twilight | Night

Sky brightness during lunar phases

Dark (first quarter) | Light (full Moon) | Dark (last quarter) | Total darkness (new Moon)

IC Inferior conjunction (Mercury & Venus only)

SC Superior conjunction

OP Planet at opposition

Meteor radiant peak

Planets in conjunction

Full Moon

First quarter

Last quarter

New Moon

CHART BY PETE LAWRENCE

ASTEROID DAY 30 JUNE

Sean Blair works for the European Space Agency (ESA) as a senior editor, covering space technology and navigation

HERA

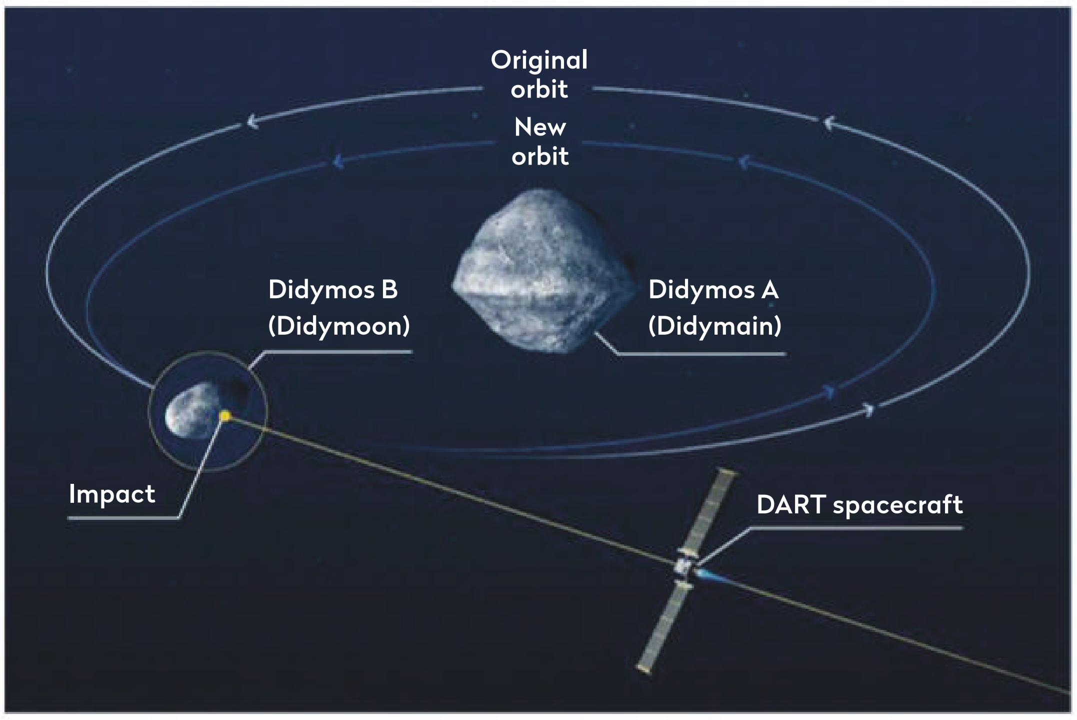
Europe's asteroid mission to defend Earth

With Asteroid Day on 30 June, **Sean Blair** looks at ESA's part in a mission that is science fiction made real – to impact a near-Earth object and alter its path

We all know that accidents can happen, but 2020 will be remembered as a year of catastrophe. The upshot is we have to pay greater attention to all kinds of near misses, including those from space in the shape of incoming asteroids, and on 30 June we do just that as the world marks Asteroid Day. Similarly, 2022 should also be a year to remember but in a quite different way. That October, humankind will test out responding to the asteroid threat by slamming a desk-sized NASA spacecraft called DART, the Double Asteroid Redirection Test, into the moonlet of a near-Earth asteroid at 6.6km per second. That historic event will mark our species' next giant leap following the Moon landing – the first time we change the orbit of a Solar System object in a measurable way.

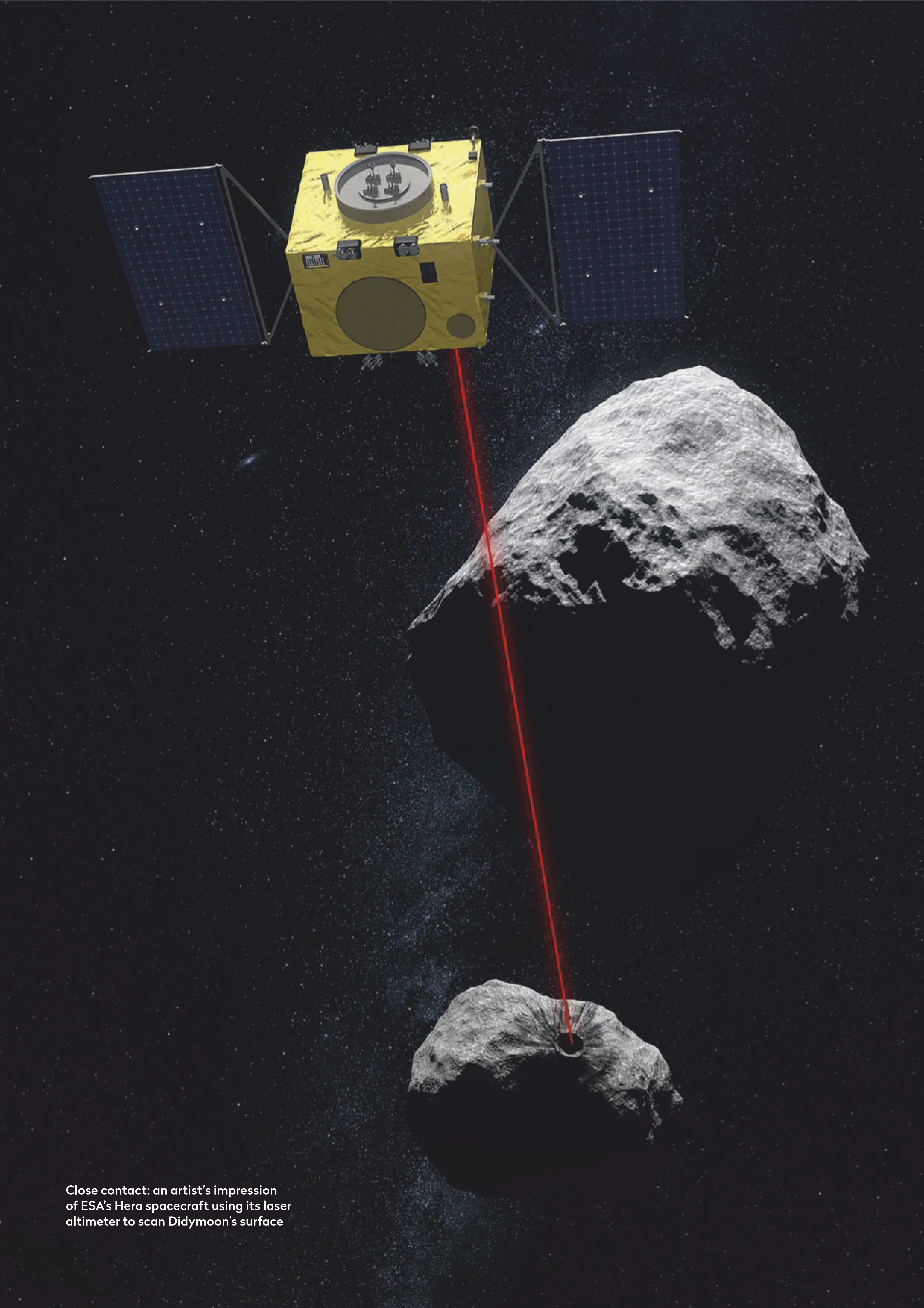
DART's target has been carefully chosen: the smaller of the two Didymos asteroids, in solar orbit between Mars and Earth. At 160m across, about the size of the Great Pyramid, Didymos B, or 'Didymoon', is in the asteroid class capable of generating casualties on a regional scale, were it to impact Earth. It orbits around the main 780m-diameter, mountain-sized asteroid. This might sound substantial, but the main asteroid has a low enough mass and gravity that Didymoon orbits around it slowly, at less than 20cm per second – a speed which makes achieving a measurable deflection straightforward. Didymoon's degree of orbital deflection will be measurable from Earth by decoding radar signals and light curves gathered via our planet's telescopes.

After DART's impact, Europe will take a lead in the historic undertaking: the European Space Agency (ESA) is finalising and launching a second spacecraft to closely investigate this unique, orbitally modified body. ESA's Hera mission, named after the Greek goddess of marriage, is due to launch in 2024. "The mission's goal is to acquire crucial collision data we can't obtain from long-distance observation," says astronomer Patrick ►

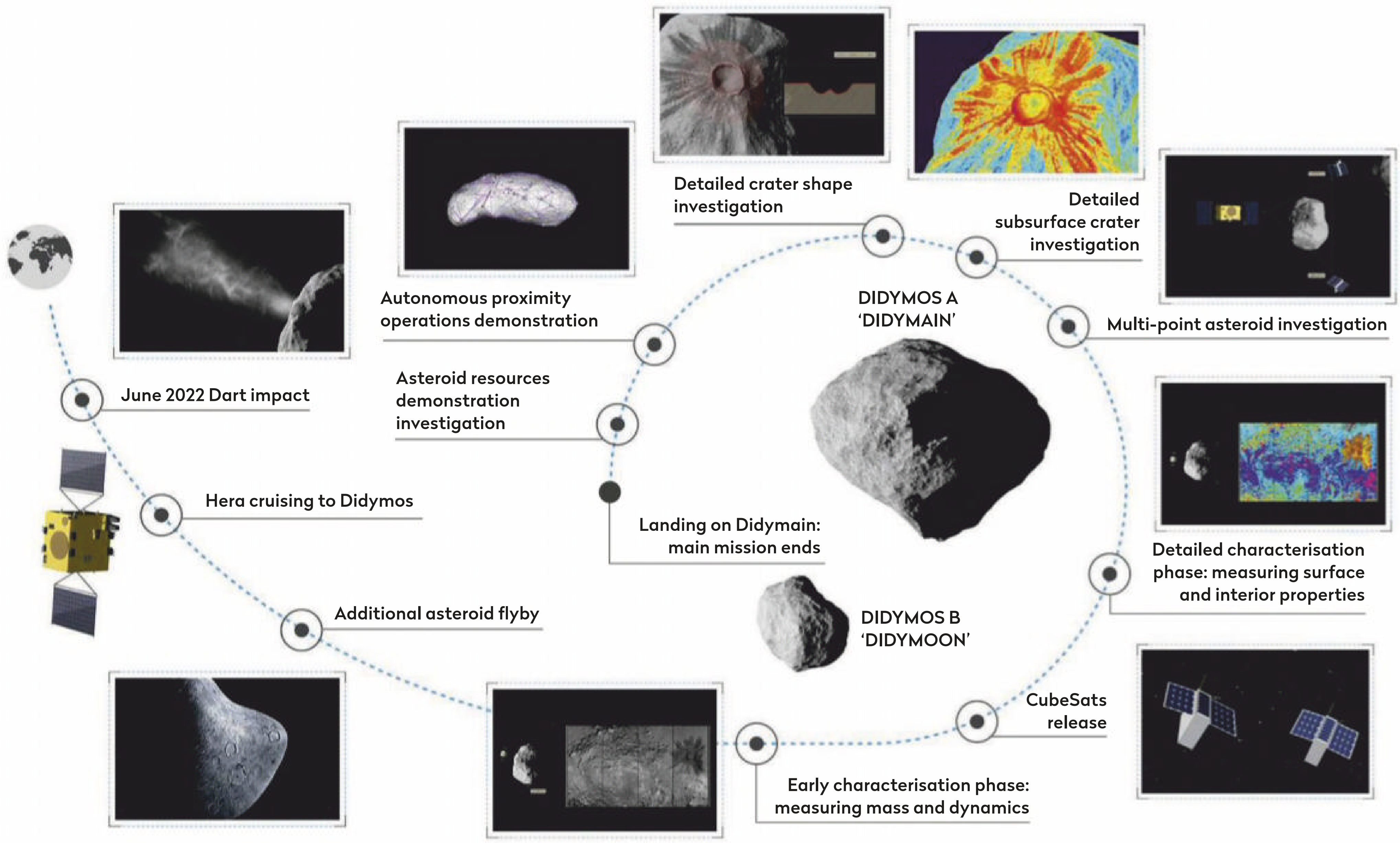


▲ **Changing lanes: in October 2022, NASA's DART spacecraft will impact with Didymoon to make it change orbit**

NASA/JOHNS HOPKINS APL, ESA - SCIENCEOFFICE.ORG



Close contact: an artist's impression of ESA's Hera spacecraft using its laser altimeter to scan Didymoon's surface



▲ **Destination Didymos: an outline of the Hera mission to the Didymos binary asteroid system, where it will examine the crater left by DART's impact with Didymoon**

▸ Michel of France's Côte d'Azur Observatory, Hera's lead scientist. "This includes measuring Didymoon's mass, structure and compositional properties, as well as taking a close-up look at the crater left by DART's impact." Hera was approved to fly by ESA's Ministerial Council late last year, marking a dramatic comeback, since the mission proposal had been withdrawn at the same venue some four years earlier.

"The [withdrawl] came after years of work on the Asteroid Impact Mission (AIM), Hera's predecessor, when the mission wasn't able to raise sufficient financial support from ESA member states," recalls Ian Carnelli, managing Hera for ESA. "However, some countries had expressed enthusiasm for the concept, so development work continued."

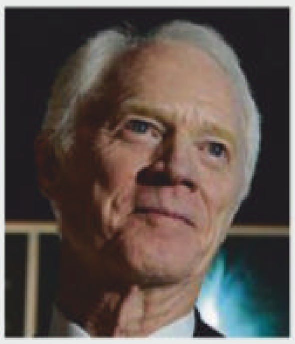
Common aims

Hera's broad mission goals remain the same as AIM's: firstly to be Europe's contribution to this grand international planetary defence experiment; AIDA – the Asteroid Impact and Deflection Assessment as the joint mission is known – will see DART and Hera mutually enhance their respective results. Secondly, Hera will gather experience of extremely low-gravity operations, which will come in handy for future asteroid resource prospecting. Thirdly, Hera will perform as much usable science in the process: it will be Earth's first ever expedition to the still mysterious class of binary asteroids that make up about 15 per cent of all known asteroids, and it will mount the first investigation of an asteroid interior through radar sounding.

But the redesigned Hera also lost some mission facets, including a small lander and a powerful laser to relay data back to mission control. The desk-sized mission does retain other ambitious elements, most notably a pair of CubeSats – shoebox-sized spacecraft built up from 10cm cubic units, able to fly much closer to the surface than Hera itself. "These two will be Europe's first CubeSats in deep space, each operating independently, with Hera as their relay mother ship," explains Carnelli. "The 'Juventas' mission CubeSat will perform the first radar survey of an asteroid's interior, employing an antenna longer than the CubeSat itself, while a second CubeSat will perform spectral measurements of both Didymos asteroids, identifying what they are made

From Apollo to asteroids

Former astronaut Rusty Schweikart is in the vanguard of defence against space rocks



Apollo 8 astronaut Rusty Schweickart is one of the founders of the B612 Foundation, a sponsor of Asteroid Day, who has spent years investigating asteroid deflection techniques.

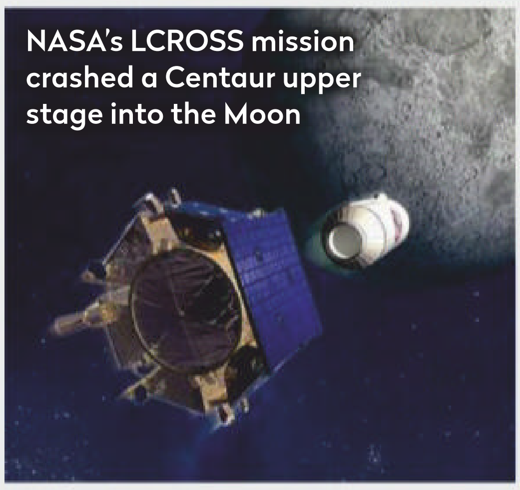
He explains: "More and more asteroids were being discovered, but nobody was talking about what to do if one comes our way. We asked if technology was at a point where it's worth considering what to do. It turned out it was: with sufficiently advance knowledge we probably could deflect an asteroid."

That work led in turn to the first inklings of AIDA, and what has become DART and Hera. "We stopped talking about a deflection mission and switched to a deflection campaign," says Schweickart. "You need an observer spacecraft as well as a deflector, to be sure the deflection has worked as planned. If it hasn't, the observer could help fine-tune the asteroid's modified orbit, serving as a 'gravity tractor' – using its own mass to tug the body in a different direction."

ESA/SCIENCE OFFICE, DPA PICTURE ALLIANCE ARCHIVE/ALAMY STOCK PHOTO, NASA, ESA/GOMSPACE

Space impacts – a brief history

The Hera mission is the latest in a line of impact missions launched from Earth



NASA's LCROSS mission crashed a Centaur upper stage into the Moon

Collisions have been a driver of Solar System history, and humans have added to their number. Apollo lunar modules and Saturn V third stages were collided with the Moon to trigger artificial 'moonquakes', which revealed valuable information about the Moon's interior structure.

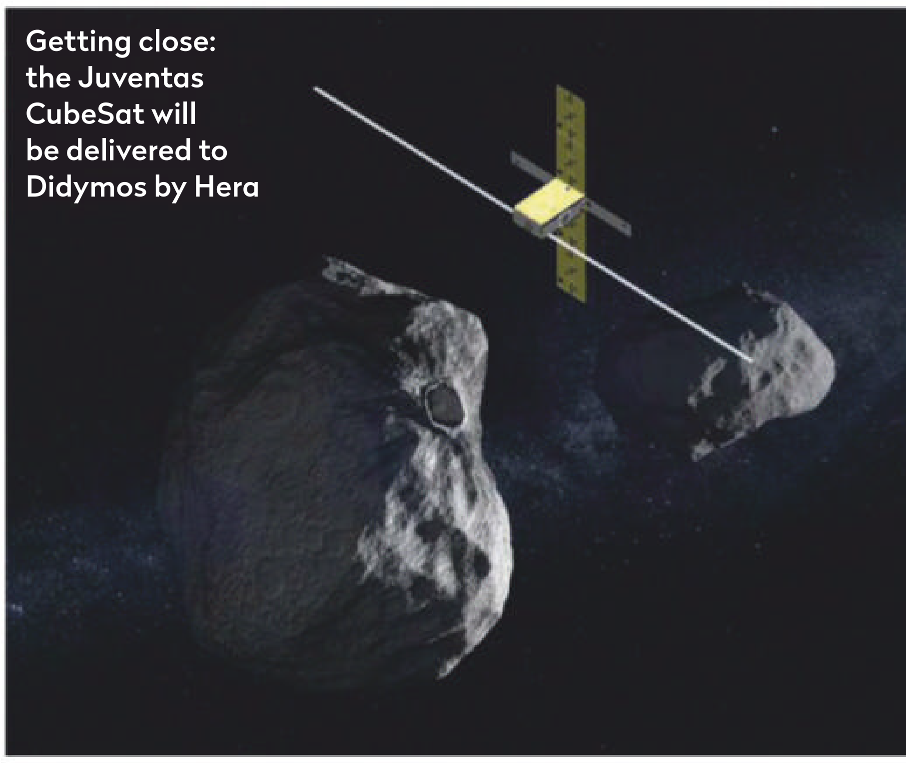
In 2005 NASA's Deep Impact collided with the comet Tempel 1 to uncover subsurface material. The large dust plume meant the crater couldn't be imaged at the time and a 2011 flyby by the Stardust mission sent back unimpressive results.

More dramatic was NASA's 2009 LCROSS mission, which slammed a Centaur upper stage at 2.5 km/s into Cabeus crater near the Moon's south pole. A 'shepherd' spacecraft flew through the impact plume, sniffing out water ice and carbon dioxide – of potential use to future colonists.

Last year, Japan's Hayabusa2 shot a copper projectile into the 900m diameter asteroid Ryugu at 2 km/s, resulting in a crater of 20m across.

The DART collision will strike an asteroid five times smaller than Ryugu with a spacecraft more than 200 times larger than Hayabusa2's 2kg projectile, moving three times faster. Its impact should deliver sufficient energy to achieve the first asteroid deflection experiment for planetary defence.

▲ Rock hard: the size of Didymoon compared to the Houses of Parliament



Getting close: the Juventas CubeSat will be delivered to Didymos by Hera

of down to individual boulders, as well as some dust investigations." The CubeSats will end their missions by touching down on either Didymos A ('Didymain') or its moonlet – although with the asteroid's low gravity it will be more like docking than landing.

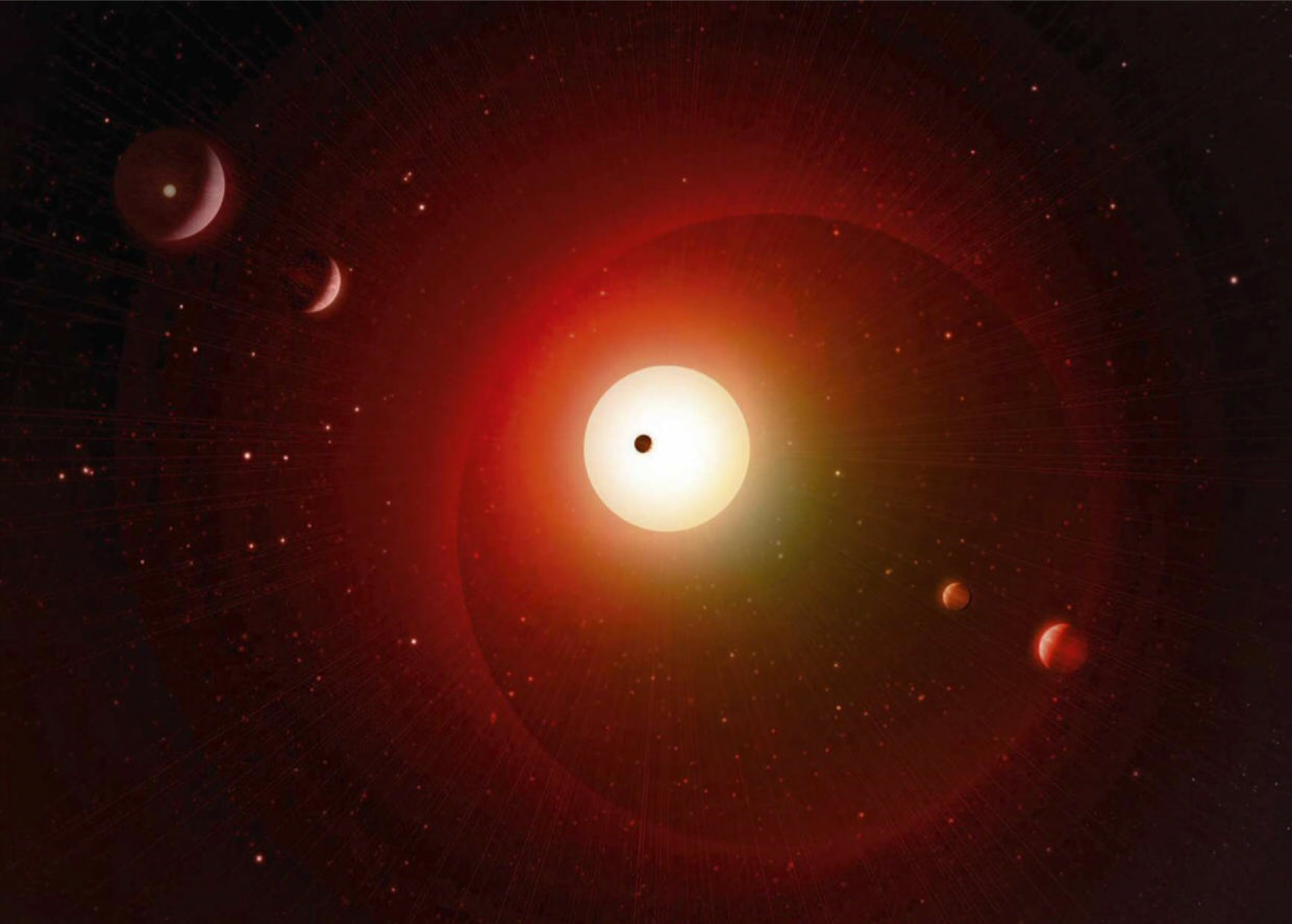
Hera's own main imager actually comes secondhand: the German-developed Asteroid Framing Camera was originally built for NASA's Dawn mission to the two largest bodies in the asteroid belt, Ceres and Vesta. "This is a flight spare, which we'll be using both for science and for navigation," says Carnelli. "When we get close we'll be performing tracking of surface features such as craters and boulders. This is both to know where we are in space with respect to the asteroid, but also for a novel method of determining Didymoon's mass – looking for small wobbles in the main asteroid's rotation relative to their combined centre of gravity." Simply measuring Didymoon's gravitiational tug on Hera's trajectory will represent a challenge, because the gravitational field of the main asteroid will swamp its moonlet.

Hera will also carry a compact 'lidar' laser altimeter to perform surface mapping, as well as a thermal infrared instrument whose temperature measurements should give an idea of the asteroid's surface makeup. In addition, the mission will see how proximity to the asteroids affects its radio link with Earth, to gain insight into their mass and internal structure.

Back on track

Less than a third the size of ESA's Rosetta comet mission, Hera will be a smart but comparatively simple spacecraft – a vision which won over ESA member states second time around. "We couldn't help but feel nervous after 15 years of asteroid deflection mission concepts research," recalls Carnelli. "It was a huge relief when Hera was approved as part of ESA's Space Safety programme, along with asteroid-detecting 'flyeye' telescopes, a new space debris monitoring system and Europe's first space junk removal mission."

Now comes the effort to make the Hera mission's 2024 launch date, which will see it arrive at the Didymos system in 2027. "It isn't such a long time away at all," says Carnelli. "And we're working around the COVID-19 pandemic as much as possible, videoconferencing with industrial partners in almost every corner of Europe."



TESS: the planet hunt CONTINUES

Though its main mission comes to an end in July, the exoplanet finder's job is far from done. **Ezzy Pearson** investigates

ELEN11/ISTOCK/GETTY IMAGES, NASA'S GODDARD SPACE FLIGHT CENTER

Inspirational: wIth an extension already granted, it's hoped that TESS's search for new planets will continue for many years

For the last two years, the Transiting Exoplanet Survey Satellite (TESS) has been watching the stars, searching for new worlds. This month it completes its primary mission, having scanned 70 per cent of the sky – an area 400 times larger than that covered by its predecessor, the Kepler space telescope; but its job is far from done. As TESS moves into a two-year extension, we take a look over what the mission has already achieved and what it still could.

Like Kepler, TESS has been tracking some 200,000 stars, watching out for the tell-tale dip in brightness as a planet passes – or transits – in front of the star. "TESS's particular niche is that it's sensitive to red dwarf stars," says Sara Seager, deputy science director for TESS. "The reason for that is that we can find small planets transiting small stars more easily than small planets transiting larger stars. The dream is to find small rocky planets in the habitable zones of their stars."

The ultimate goal is to find 50 new small planets with accurate size and mass measurements, which the TESS team will then distribute to the world. "From TESS itself you just get the planet's size and the orbital period," says Seager. "You can do follow up mass measurements of planets, which takes a very long time and for a lot of them we can't. People are busy finding planets."

At the time of writing, TESS had identified 1,835 planetary candidates. To investigate these further, the project has a team of around 500 individuals from 100 institutions doing follow-up observations.

Overcoming obstacles

The first step of this follow-up is confirming the planet is actually a planet. The TESS team take very precise images of the host star to make sure it's not a pair of close binary stars, which can produce similar patterns of rising and falling brightness.

Normally these observations would happen within a few months of TESS discovering a candidate, but the global COVID-19 pandemic has forced many of the telescopes that would do these observations to close their domes. "The follow-up has really stalled," says Seager. "Objects are only favourably placed in the sky for a short amount ▸

Diving into exoplanet atmospheres

The planets TESS finds will keep exoplanet scientists busy for years

One area that exoplanet scientists are becoming increasingly interested in is taking a deeper dive into the atmospheres of exoplanets. Doing so is difficult, as it requires picking out the tiny fraction of starlight that passes through these alien atmospheres when the planets transit their stars.

By comparing the chemical signature of a star when it has a planet in front of it to when it doesn't, astronomers can work out what elements are in its atmosphere. This is easiest to do when the background star is bright. "The number of photons passing through the atmosphere is key to how much of a signal you can ultimately find," says Sara Seager, deputy science director for TESS. "Planets that have a puffier atmosphere are better as well."

To ensure that our own atmosphere doesn't drown out the signal, this follow-up is usually done with space-based telescopes, be it with the new dedicated scopes such as ESA's Cheops, or more general-purpose scopes such as Hubble and the upcoming JWST.

Such observations are difficult and can take a long time to both take and process, but over the coming decade we could soon find out what alien skies are like on planets around other stars.

▸ of time. It could delay confirming planet candidates for five months."

Once confirmed, astronomers work out the size of the planet by measuring how much the star's brightness goes down during the transit – the bigger the dip, the bigger the planet. These planets appear to range in size from around the radius of Earth to several times the width of Jupiter, with the most common type being mini-Neptunes – planets around two to three times the size of Earth. "These have no Solar System counterpart," says Seager. "We don't know what they are. Are they all different? Are they just one type of planet? TESS has been really successful in finding those around both Sun-like and dwarf stars."

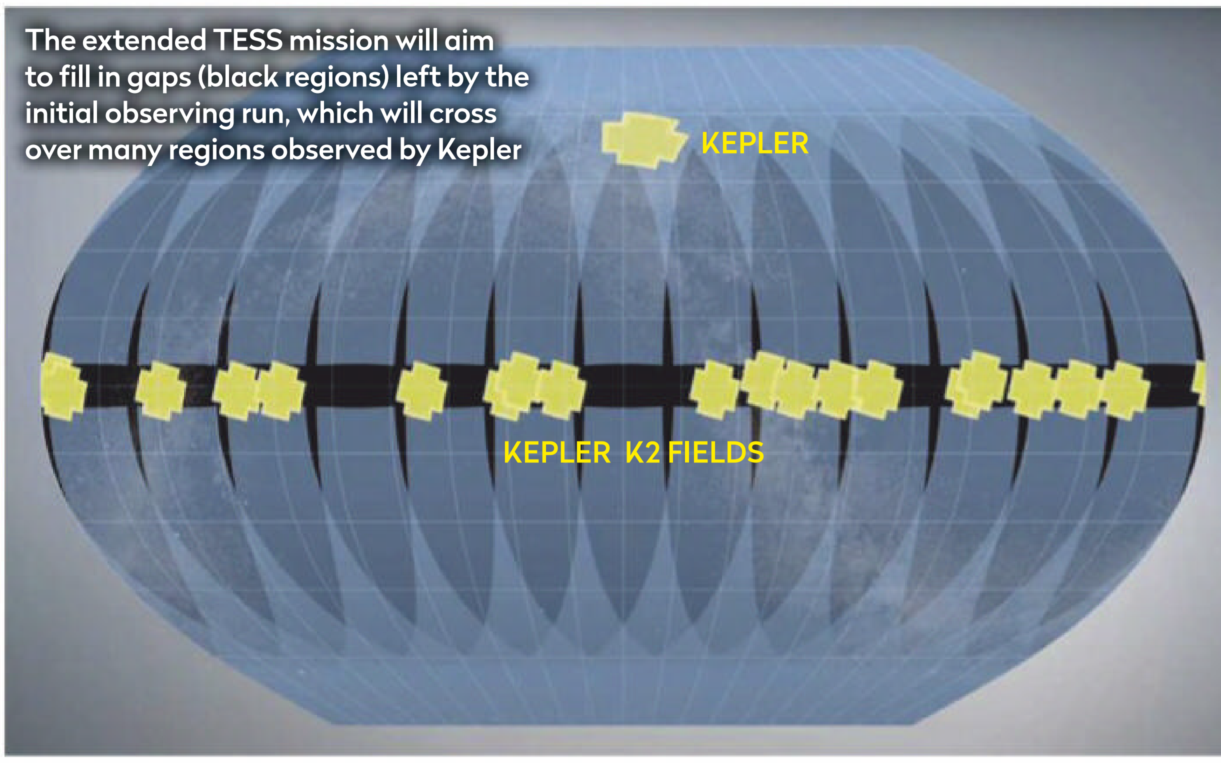
The size distribution also backs up something that was found by the Kepler space telescope – there is a curious lack of planets between 1.5 and 2 Earth radii, a range known as the Fulton gap. "TESS has found planetary systems on either side of that gap," says Seager. It's thought the key to the gap lies in the planet's atmospheres – stellar wind and radiation strips away the gases from the smaller planets, while the upper edge marks the point where planets are large enough to hold onto their atmospheres. "In the future we hope to look at their atmospheres with other telescopes and find why the gap appears to exist and try to make sense of it," says Seager.

A precise approach

The final stage of TESS's follow-up is to determine the masses of planets. Doing this requires precise spectroscopy to measure the stellar wobble caused by the planet pulling on the star. "Those are very specific instruments and there are only a handful of them around the world," says George Ricker, TESS's principal investigator. "We're getting close at this point to having the 50 measured masses."

Once the team have both size and mass in hand it's possible to work out the density of the planet, giving an indication of whether it's rocky or gaseous. At this point, the TESS team's job is largely done; it's time for other missions and projects to pick their favourite planets and take a closer look.

One of the forefront areas of exoplanet research at the moment is analysing these alien atmospheres in detail. By looking for key chemicals in a planet's atmosphere, such as oxygen, carbon dioxide or water, astronomers can begin to understand what these planets are like, which is particularly important for planets like mini-Neptunes which have no counterpart in the Solar System. This in turn helps planetary



The extended TESS mission will aim to fill in gaps (black regions) left by the initial observing run, which will cross over many regions observed by Kepler

It's time for other missions and projects to pick their favourite planets and take a closer look

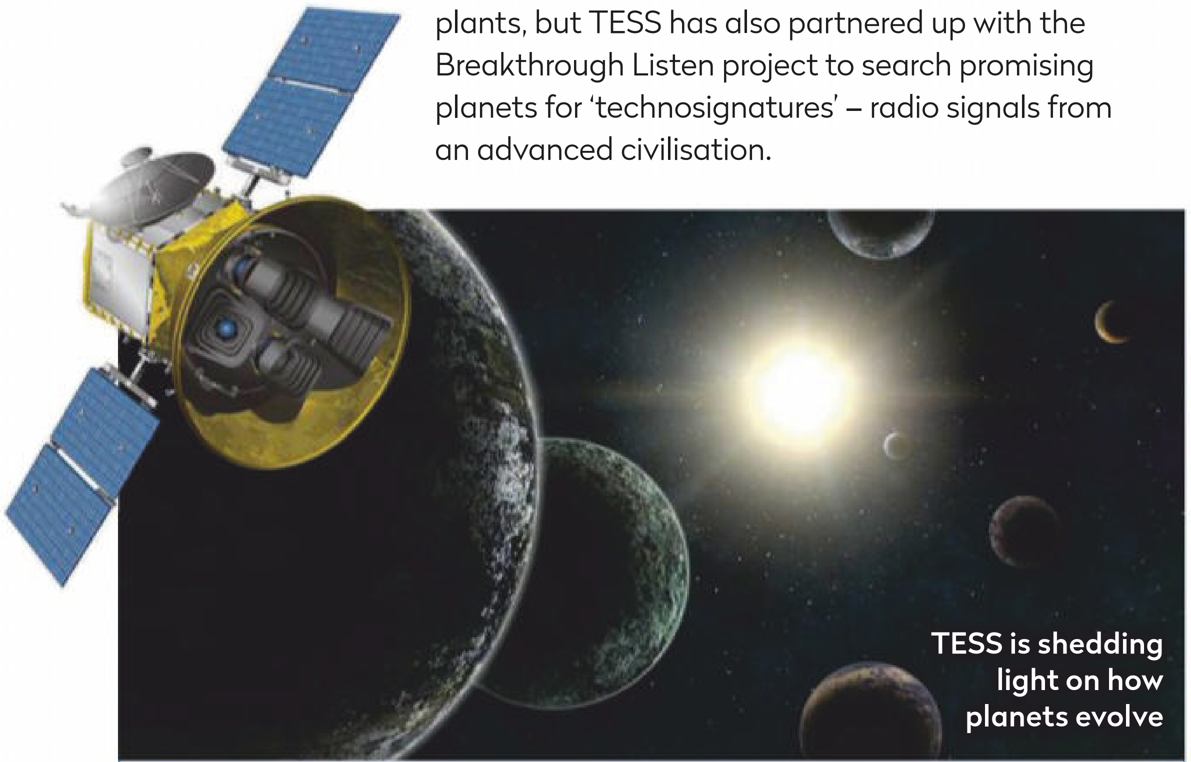
Dr Ezzy Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

JAMESMCQ24/ISTOCK/GETTY IMAGES, NASA GODDARD, DOTTEDHIPPO/ ISTOCK/GETTY IMAGES, OORKA/ISTOCK/GETTY IMAGES, NASA

▸ **Searching for life: as well as looking for traces of bacteria and plants, TESS is searching for signals from advanced civilisations**

scientists to craft more complete theories about how planets grow and change to create the planetary systems we see today.

One particular area that always draws attention is hunting down planets which might show signs of life, known as biosignatures. Mostly, these are chemical imbalances caused by the presence of bacteria or plants, but TESS has also partnered up with the Breakthrough Listen project to search promising planets for 'technosignatures' – radio signals from an advanced civilisation.



TESS is shedding light on how planets evolve

TESS's top five

The programme has already uncovered a great many worlds. Here are some of the most noteworthy

TOI 700d
TESS's first Earth-sized world found within the habitable zone. Its orbit is only 37 days long, meaning it's much closer to its star, however the star is a red dwarf and so much cooler than the Sun.

TOI 270 system
The planetary system TOI 270 has two mini-Neptunes. Planetary scientists will compare them to see how they differ, given both planets formed in the same environment.

Pi Mensae c
The first new planet that TESS discovered back in 2018. It's around twice the size and five times the mass of Earth, and orbits a Sun-like star once every six days.

TOI 1338
A circumbinary planet, TOI 1338 orbits around a tight binary pair of stars. The planet candidate was initially dismissed, before being spotted by Wolf Cukier, a high school intern working at NASA.

HD 203949b
TESS confirmed that the host star has been through its red giant phase – an event which should have destroyed its planet, which was originally found by Kepler.

The possibilities of TESS go far beyond merely looking for exoplanets, however. As it was observing the stars, TESS's four cameras were also taking wide-field images of the sky. Unlike most projects, which jealously guard their data for a few months, all of TESS's data is made publicly available as soon as it's ready. "That's an aspect of why TESS has been so successful," says Ricker. "We've been able to instigate this feeling of collaboration rather than competition."

TESS observes the sky in 24 x 90° sections – about four times the size of Orion – taking images every 30 minutes or so. These kinds of observations are perfect for spotting transient events, such as supernovae, and TESS finds around 100 of these every year.

Looking ahead

Yet despite this wide coverage, TESS's primary mission only observed around 70 per cent of the sky. As the mission now heads into its extension the spacecraft will aim to fill in these gaps. Notably, the satellite will cover the ecliptic plane, though these observations will be looking at worlds a little closer to home. "There's a lot of Solar System science that we're going to do," says Ricker. "TESS is able to detect some 100,000 asteroids, Kuiper Belt objects and trans-Neptunian objects."

The extension will also allow TESS to go back over areas which were only briefly observed, allowing astronomers the chance to uncover planets further from their stars with a longer wait between successive transits. "We should be able to find many more habitable-zone planets on which liquid water might be able to exist," says Ricker. "For something like Earth, you'd need to observe the Sun for a year to see a transit and that's why this extended mission is going to be really important."

The latest mission extension will last until 2022, but the TESS team have plans long beyond that. "We hope to carry on operations to 2028 as the satellite is operating really well. We think we'll be able to observe for at least a decade, hopefully a lot more," says Ricker.

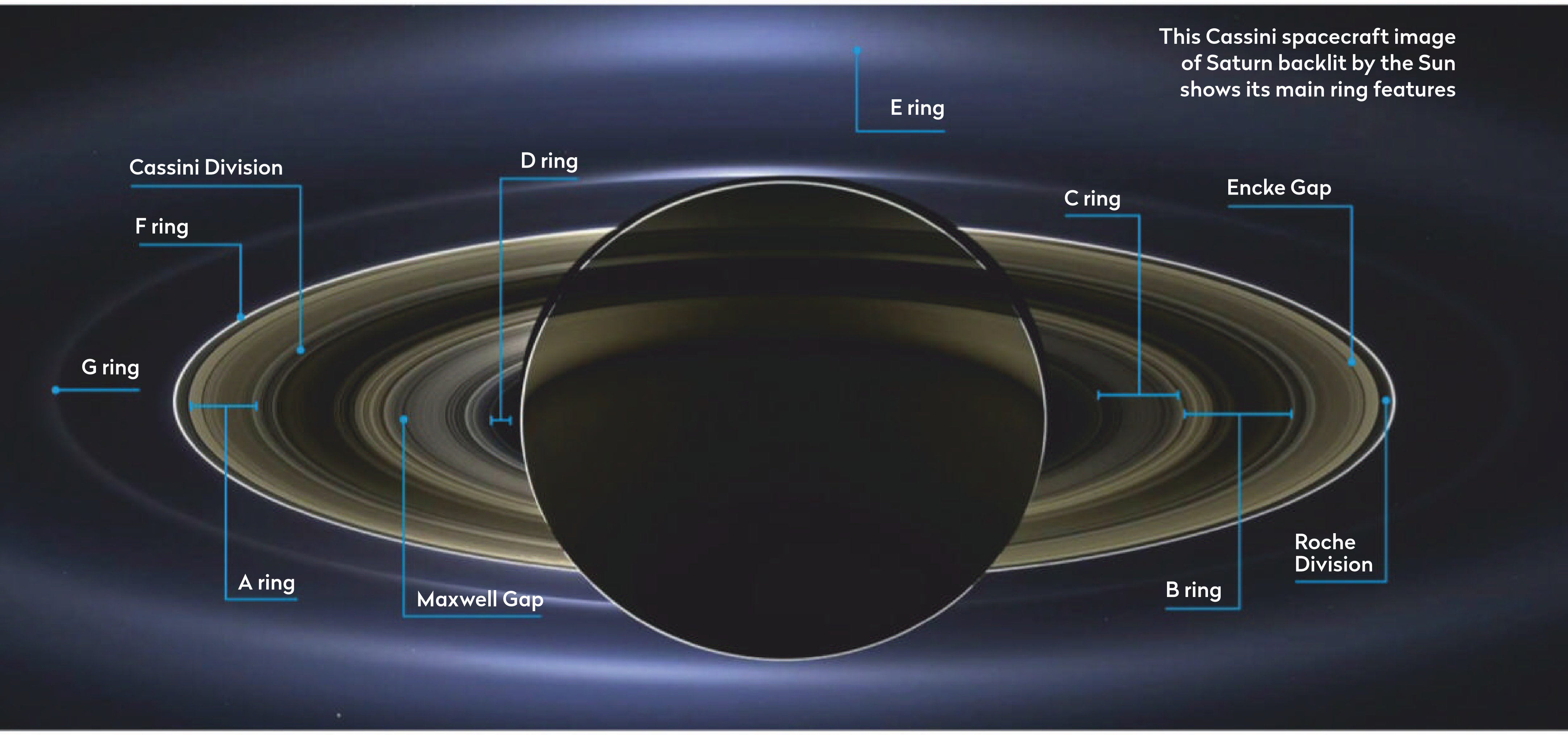
The primary mission of TESS might now be complete, but its task is far from finished.

The fundamentals of astronomy for beginners

EXPLAINER

Saturn's rings

The hoops around the second-largest planet are iconic, but what do we know about them?

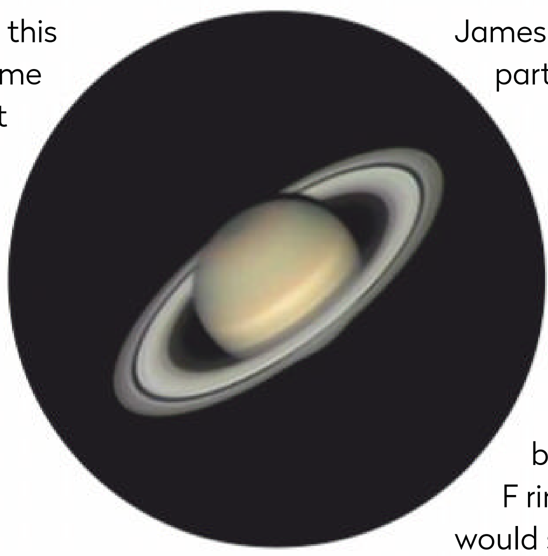


This Cassini spacecraft image of Saturn backlit by the Sun shows its main ring features

With Saturn at opposition this month, now is a great time to see it. Even a modest scope will reveal the distinctive ring system. Other planets may have rings, but none as spectacular as Saturn's.

Galileo was first to observe the rings in 1610, but he was unsure if he was seeing two moons or whether Saturn had handles or 'ears'. And why did they seem to come and go every year or so?

In 1656 Christiaan Huygens was first to suggest that Saturn had a ring that was not attached to the planet, and in 1675 Giovanni Domenico Cassini identified the formation as being composed of a series of rings and gaps, identifying the A and B rings and the largest gap, which was named the Cassini Division after him. It was thought the rings were solid or liquid, but in 1859 James Clerk Maxwell proved they were made of particles and were orbiting Saturn independently.

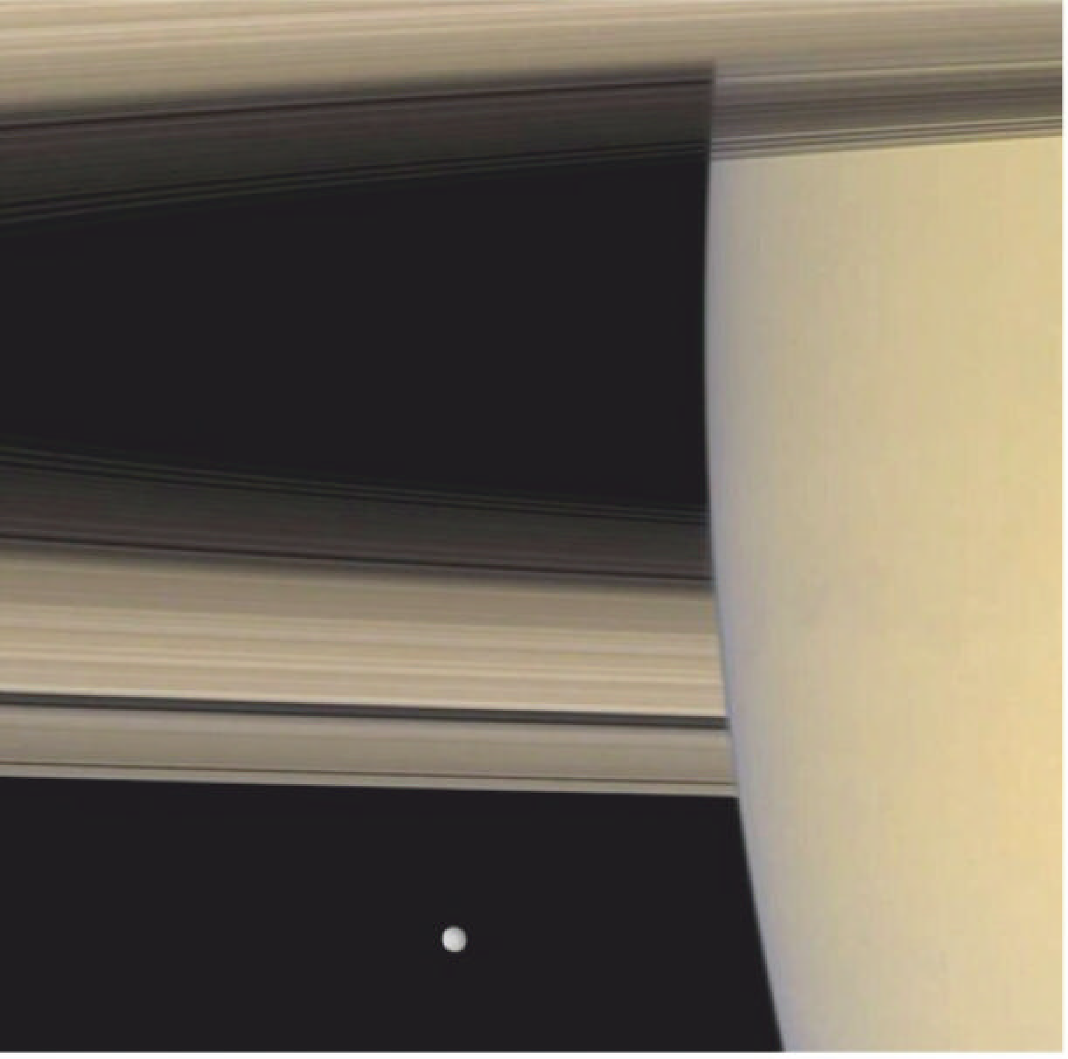

▲ Majestic: viewed through a telescope Saturn and its rings are a fantastic sight

The main rings have been named in the order of their discovery; so the C ring was discovered in 1850, the D ring in 1933 and the E ring in 1967. The diffuse Phoebe ring, discovered in 2009, extends an enormous 6–16.2 million km from Saturn.

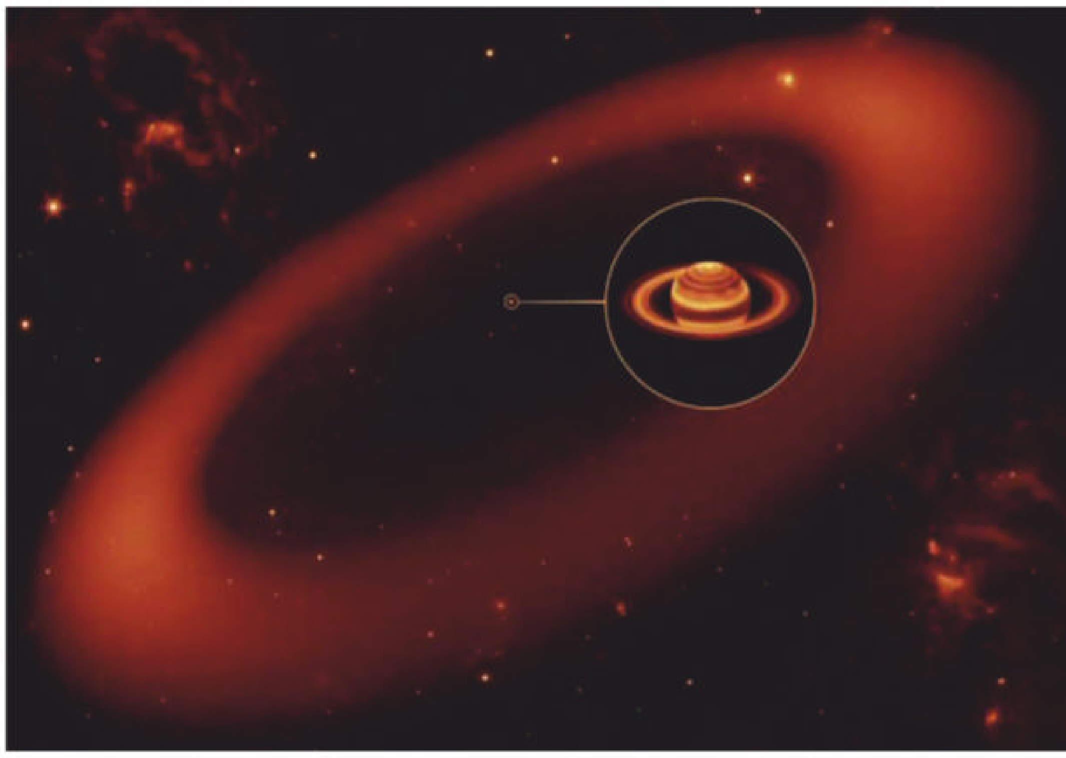
Four missions have had close encounters with Saturn so far. Pioneer II was first, passing by in 1979 when it discovered the very narrow F ring. Normally collisions between particles would spread the ring both inward towards the planet and outward to create a wide, diffuse ring. But the F ring is kept narrowly confined by the influence of two shepherd moons, called Prometheus and Pandora.

In 1980, Voyager 1 identified the G ring, and the following year Voyager 2 discovered several smaller ringlets when it passed by. In July 2004, the Cassini

NASA/JPL-CALTECH/SSI, SEBASTIAN VOLTMER/CCDGUIDE.COM, NASA/JPL/SPACE SCIENCE INSTITUTE, NASA/JPL-CALTECH/KECK, ERICH KARKOSCHKA (UNIVERSITY OF ARIZONA LUNAR & PLANETARY LAB)AND NASA/ESA, NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE



▲ **Mimas is dwarfed by Saturn's rings in this image, despite the fact that their entire mass is equal to that of the tiny moon**



▲ **An artist's impression of the Phoebe ring, the largest of Saturn's rings, which was discovered in 2009 by the Spitzer Space Telescope**

mission began its 13-year visit to the planet, discovering many new moons and ringlets.

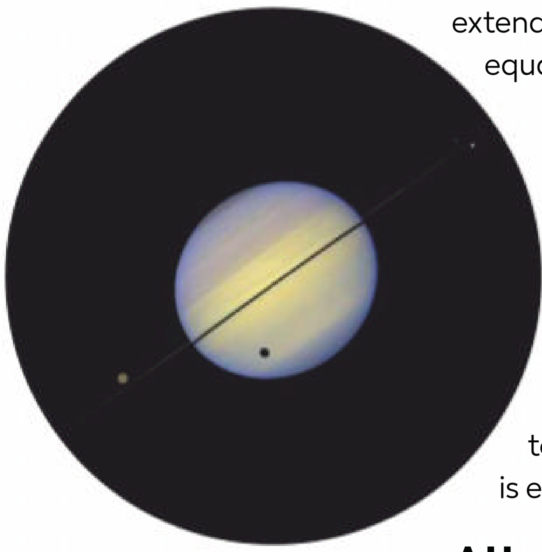
The particles in the rings consist of almost pure water ice; this makes them extremely bright. Saturn's albedo, the amount of light it reflects, varies from –0.5 when the rings are edge-on to +0.9 when they are fully open. The particles range from the size of a sand grain to 10m or more in diameter. The gaps are not well-defined empty spaces, but are areas where particle density drops. The largest of these, the Cassini Division, is 4,700km wide.

Building blocks

From inner to outermost, the main structures are: the D, C and B rings; Cassini Division; A ring; Roche Division; F ring; Janus/Epimetheus ring; G ring; Methone and Anthe ring arcs; Pallene ring; E ring and finally the Phoebe ring. Many of these have their own subdivisions, gaps, structures and moonlets within.

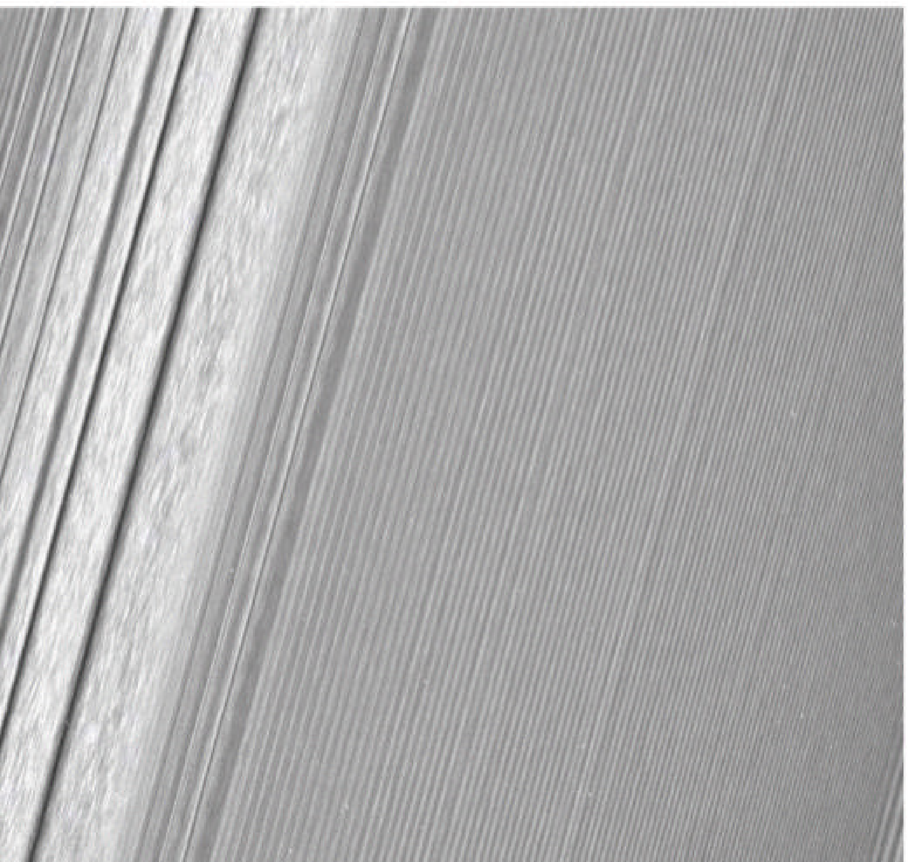
The rings orbit in the same direction as Saturn but at different rates, the inner rings faster than the outer ones in accordance with Kepler's third law. The main rings extend from 7,000km to 80,000km from the planet's equator, yet they are only an average of 10m thick.

The disappearance of the rings that so perplexed Galileo is due to the 27° tilt of Saturn's axis to the ecliptic. From Earth we see the rings from different angles as both planets orbit: first from below, then they almost disappear as we see them edge on, then they widen again as we see them from above and then they appear edge on again, so the rings seem to vanish roughly every 15 years. Their total mass is equal to that of Saturn's moon Mimas.



▲ **Every 15 years Saturn's rings seem to disappear when viewed from Earth**

Jenny Winder is a freelance science writer, astronomer and broadcaster



◂ **Rich textures: an image taken by the Cassini spacecraft during a close flyby in 2017 reveals the exquisite detail of Saturn's A ring**

All rings considered

The origin of Saturn's rings has been hotly debated. One theory is that they are all that remains of one of Saturn's moons that was ripped apart by gravitational forces when its orbit decayed, bringing it too close to its parent planet. That would mean the rings are younger than the planet. Another theory is that the rings are the same age as the planet, being remnants of the nebula from which Saturn formed.

In April 2017 at the end of Cassini's tour of the Saturn system, the spacecraft performed the Grand Finale phase of its mission, passing between Saturn and its rings 22 times before diving into and burning up in the planet's atmosphere. Data from these acrobatics on the rings' brightness and purity revealed they may have formed just 100 million years ago, when dinosaurs still ruled the Earth. If they were older, the theory goes, they would have been darkened over time by cosmic dust, although other scientists suggest that recycling of material within the rings, as particles collide, break apart and reform, could dilute any pollutants.

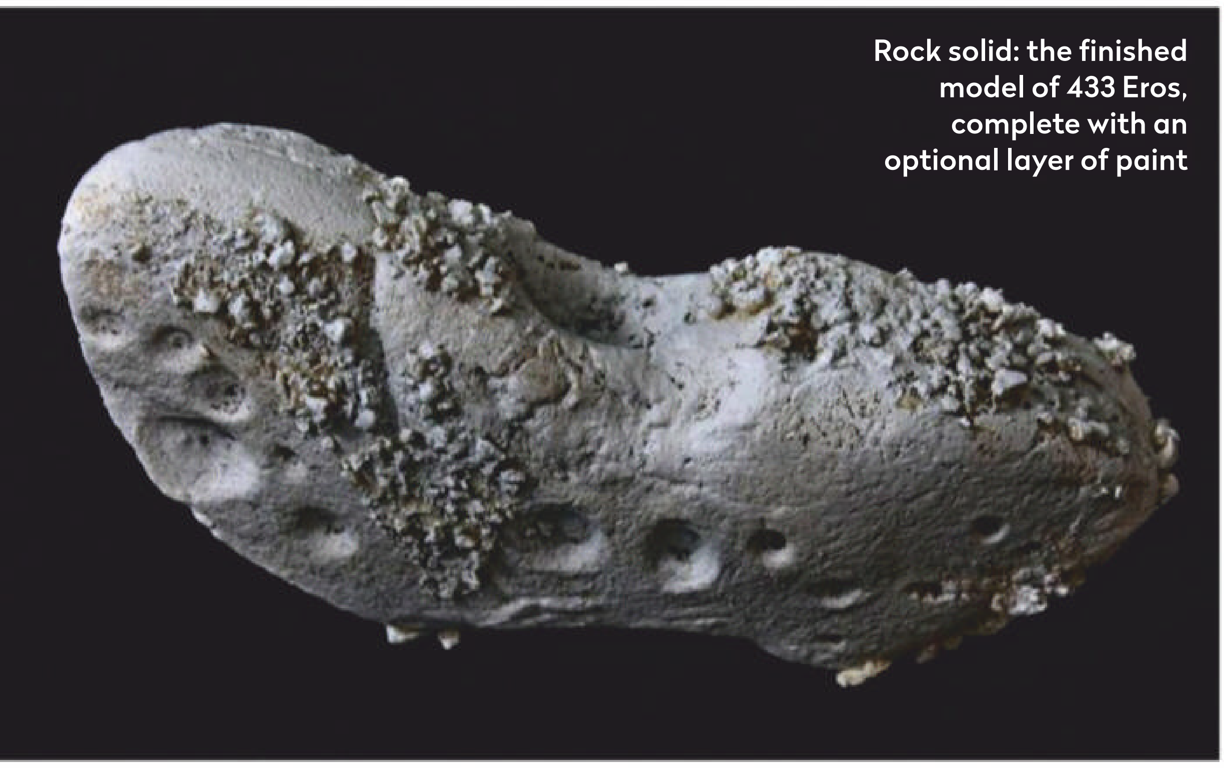
However they were formed, the rings are continually losing material in the form of an icy rain falling onto Saturn, at a rate of a swimming pool full of material every half hour. There's still plenty of time to view them: it's estimated they won't be gone for good for 100 million years.

DIY ASTRONOMY

FAMILY FRIENDLY PROJECT

Model your own asteroid

Increase your knowledge of 433 Eros and learn about its formation

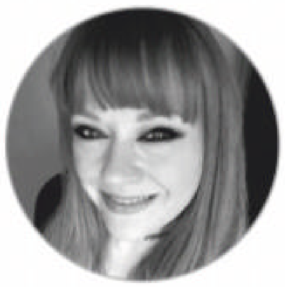


Rock solid: the finished model of 433 Eros, complete with an optional layer of paint

Asteroids are small, rocky bodies, most of which orbit the Sun in the asteroid belt between Mars and Jupiter. These space rocks are leftover material from the formation of the Solar System, and although ground-based observations of asteroids can be a little underwhelming due to their low surface brightness, studying them is important for our understanding of planetary formation.

Making an asteroid model allows you to study its morphology in three dimensions and is a fun activity; combining astronomy with crafts is a great way to engage the whole family, especially children. You can make the model using salt dough, which requires only three ingredients and you probably already have these in your store cupboard. At the time of writing, certain kinds of flour may be more difficult to find than usual. The good news is that any kind will work, so just use what you have. You also don't need any special modelling tools. Just use your hands for the basic shape and then create the details with pens and pencils.

Our model is of the asteroid 433 Eros. It's an elongated, shoe-shaped object that measures 34.4km x 11.2km x 11.2km with a mean diameter of 16.8km. It was discovered in 1898 and is one of approximately 250 near-Earth asteroids (NEAs). Unlike main belt asteroids, NEAs are thought to be either dead comets or fragments from main belt asteroid collisions. In 2000, Eros was orbited by NEAR Shoemaker mission which landed on the asteroid the following year. During this mission Eros was photographed and these high-resolution images can be used as reference photos for the model. An online 3D video animation showing the asteroid from different angles is also helpful.



Mary McIntyre is an astronomer and dedicated astro imager based in Oxfordshire

Make and bake

Salt dough is quite heavy, so we found it best to make this model in two pieces and glue them together once baked. The dough is baked at a low temperature and due to its size the model took nearly 24 hours to bake. However, if you use two parts flour to one part each of salt and water, you can adjust the quantities to make your model smaller. Painting is optional but can give an authentic look; we used a matt grey colour to mimic the low brightness of asteroids.

There are some interesting features on Eros, including different-sized impact craters. Parts of the surface are strewn with rocks and these are thought to have been caused by seismic shockwaves that have turned small craters into rubble. By making this model you can teach the family about planetary and asteroid formation, how impact craters form and how different lighting angles can affect the way these features look. You can also talk about seismological activity within asteroids, and the fact that Eros has enough gravity for a spacecraft to successfully orbit it. Once your model is finished, you can try to recreate NEAR Shoemaker's photos. After completing this project, you'll know that Eros is so much more than an unremarkable, faint 'star' in our skies.

What you'll need

- Any kind of flour (250g), salt (125g) and water (125ml).
- Tools for sculpting: you don't need any special tools, we just used different-sized pens and pencils.
- PVA glue; acrylic craft paint (optional): we mixed white paint with a tiny bit of black to make a pale grey.
- Reference images: online photos taken from various angles, plus a YouTube animation, can be found at **https://youtu.be/vXv--TMefbs**.

Step by step

Step 1

Mix the flour and salt together then slowly add the water while mixing with a wooden spoon. Aim for a texture that is stiff enough to hold its shape without being too dry, otherwise it could break

Step 2

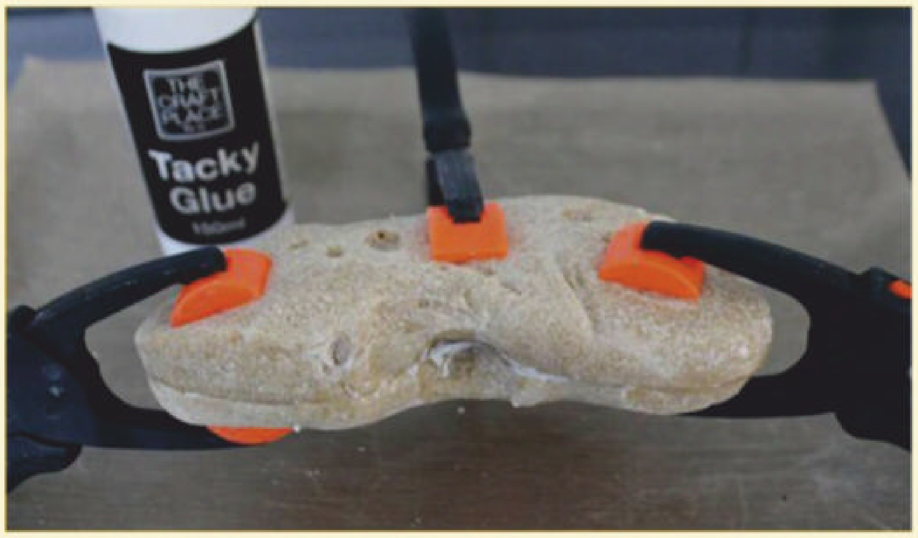
Gently knead the dough for a couple of minutes until it's smooth and pliable. If it's too wet add a bit more flour, if it's too dry add a bit more water, the important thing is that it is firm but pliable.

Step 3

Using your reference photos begin to mould the dough into the correct overall shape. We found it best to make the model in two halves split lengthways down the middle. Make sure you check multiple photos from different angles to get the shape right.

Step 4

Create the details such as craters and markings using whatever modelling tools you have, such as pens and pencils. Also make lots of small rocks using any leftover dough – these can be glued on at the end to create a good effect.



Step 5

Set the oven to its lowest temperature and bake the model pieces on parchment paper with their flat sides face down; this will take several hours. The small pieces of rubble can air dry to be added on in the last step.

Step 6

Once cooled, glue the two halves together and sand any rough edges with sandpaper or an emery board. Stick the rubble into the asteroid surface with PVA glue then paint it. When fully dried, seal it with a layer of PVA glue. Remember, this is not for eating!

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

Get ready for the Great Conjunction

Start practising now to get your best images of Saturn and Jupiter together in December

▲ **Historic event: the conjunction of Jupiter and Saturn on 21 December 2020 is the closest since July 1623**

The chances are that lately you've seen Jupiter and Saturn low in the southern part of the sky. Jupiter stands out as it's so bright, while Saturn is dimmer but fairly obvious to the east (left as seen from the UK) of Jupiter. Once you've identified them, both look impressive.

During July, the apparent separation between them increases from 6.1° to 7.7°, but this trend is not set to continue. During the year's latter part, both planets will appear to move closer together, heading towards an event known as the Great Conjunction. This is set to occur on 21 December when they will appear separated by 6.1 arcminutes, or 1/5th the apparent diameter of the Moon. If this sounds like a narrow conjunction, you'd be right. Both planets haven't been seen this close since 1623, making this a special event.

Forward planning will reap great rewards. Now is the time to start imaging the pair against background stars to get results which can be presented together to show how the Great Conjunction occurs.

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

How you plan is up to you, but here are a few pointers. A series of wide-field images is a good way to show the planets in context with a horizon, but bear in mind that 6.1 arcminutes is a small angular size. If you intend to take photos of the Great Conjunction at the same scale through to December, by the time you get to within a few days of the event, the pair will lose their duality, appearing as a single dot in the sky in wide-field photos.

You can decide to close in on them now, choosing a field of view that shows both planets virtually filling the frame. They can be shown coming closer as separate entities, up to the point of conjunction. The closeness of the conjunction may cause problems regardless. An alternative approach is to use a wide-angle setup up to the point where they start to get close. Then, make a feature in your presentation of having increased your image scale; this will free you up for capturing the final conjunction image, with close-up photos taken through a long focal length lens or a camera attached to a scope.

Great expectations

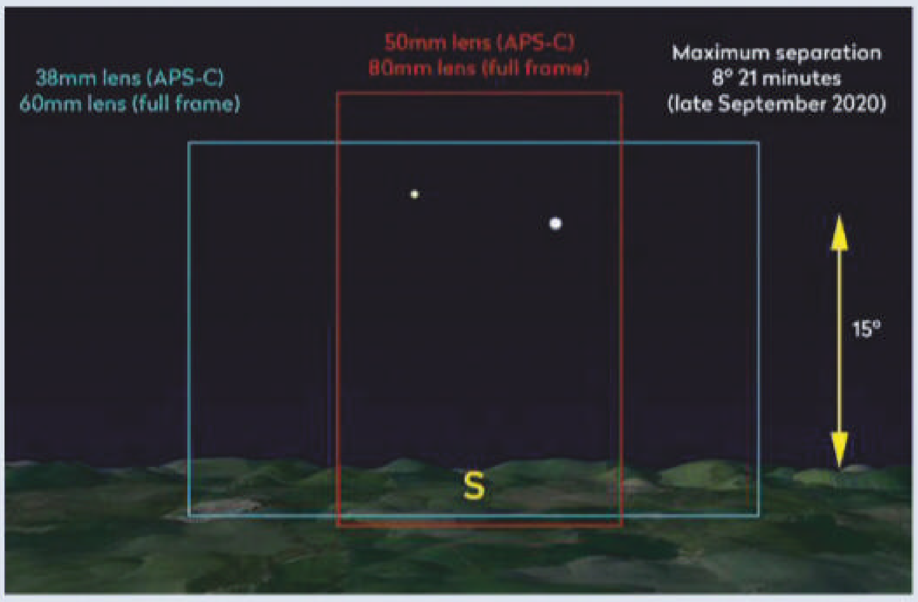
At Great Conjunction, there's the exciting prospect of being able to image both planets as discs in the same field of view. Here, a scope is recommended, as it's the best method of increasing image scale to optimise the field of view to the separation of the planets. Using a planetary camera at a low image scale will allow you to capture multiple frames for registration-stacking, giving an opportunity to produce sharp results. Remember, it may also be possible to capture both planets using a smartphone camera held up to the eyepiece of a scope. With both methods, it'll pay to practise early.

Recommended equipment: Full frame camera with a lens of focal length 80mm or a non-full frame camera with a 50mm lens. Tripod and remote shutter release.

Send your images to:
gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

Step by step

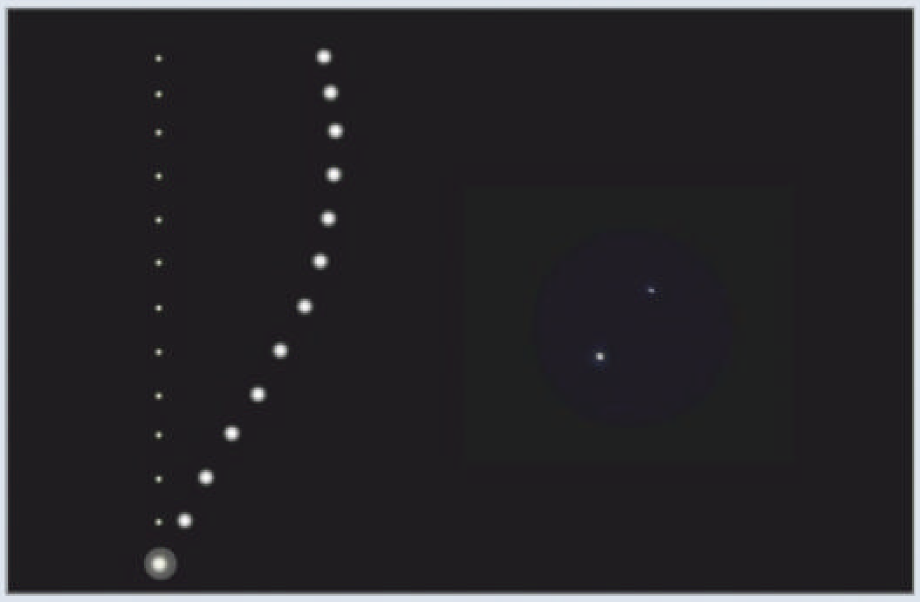


STEP 1

For wide-field shots to include some horizon, use a 50mm or shorter lens on a non-full frame camera, or an 80mm or shorter lens on a full-frame model. This gives a field of view approximately 25 x 17°, which will be sufficient to show both planets and a section of horizon in portrait orientation regardless of the time of year.

STEP 2

At the suggested focal lengths in Step 1, exposures should be kept to 10" or less to avoid trailing. In order to facilitate this, open the camera's aperture fully (lowest f-ratio) then close it by a stop or two to reduce lens distortion. Use a mid-value or lower ISO; set the lens focus to manual and focus as accurately as possible on Jupiter.

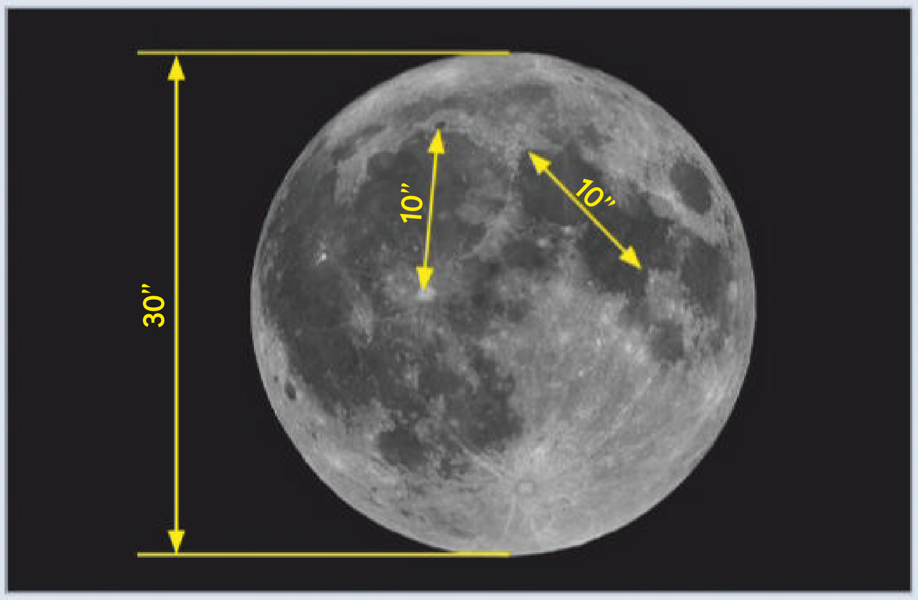


STEP 3

The Great Conjunction of Jupiter and Saturn occurs during a short window of visibility in December. Forward planning really helps as you'll need to ensure that wherever you intend to photograph from has a clear, flat horizon over towards the southwest – unlike in the above example.

STEP 4

There are many ways to present your photos. Cutting a selection with the planets in a narrow rectangle is one method – the rectangles being arranged in a long column to show changes in their apparent separation. Be prepared to break the style around the Great Conjunction when more image scale is required.



STEP 5

Use the Moon to judge the field of view you'll need to cover if you intend to use a planetary camera or smartphone. When the Moon's visible, you'll need to be able to cover an area roughly one-third the apparent size of the Moon's diameter to capture the planets together well. This equates to an apparent size of 10 arcminutes.

STEP 6

If you want to try and photograph the Great Conjunction using a smartphone, most should record the two planets as dots when they are wide apart. As they come together, try pointing down the eyepiece of a scope on Jupiter, to capture as best you can. Refine your process every clear night so you're ready for both planets.

Expert processing tips to enhance your astrophotos

ASTROPHOTOGRAPHY PROCESSING

CAUTION
Never image or observe the Sun with the naked eye or any unfiltered optical instrument

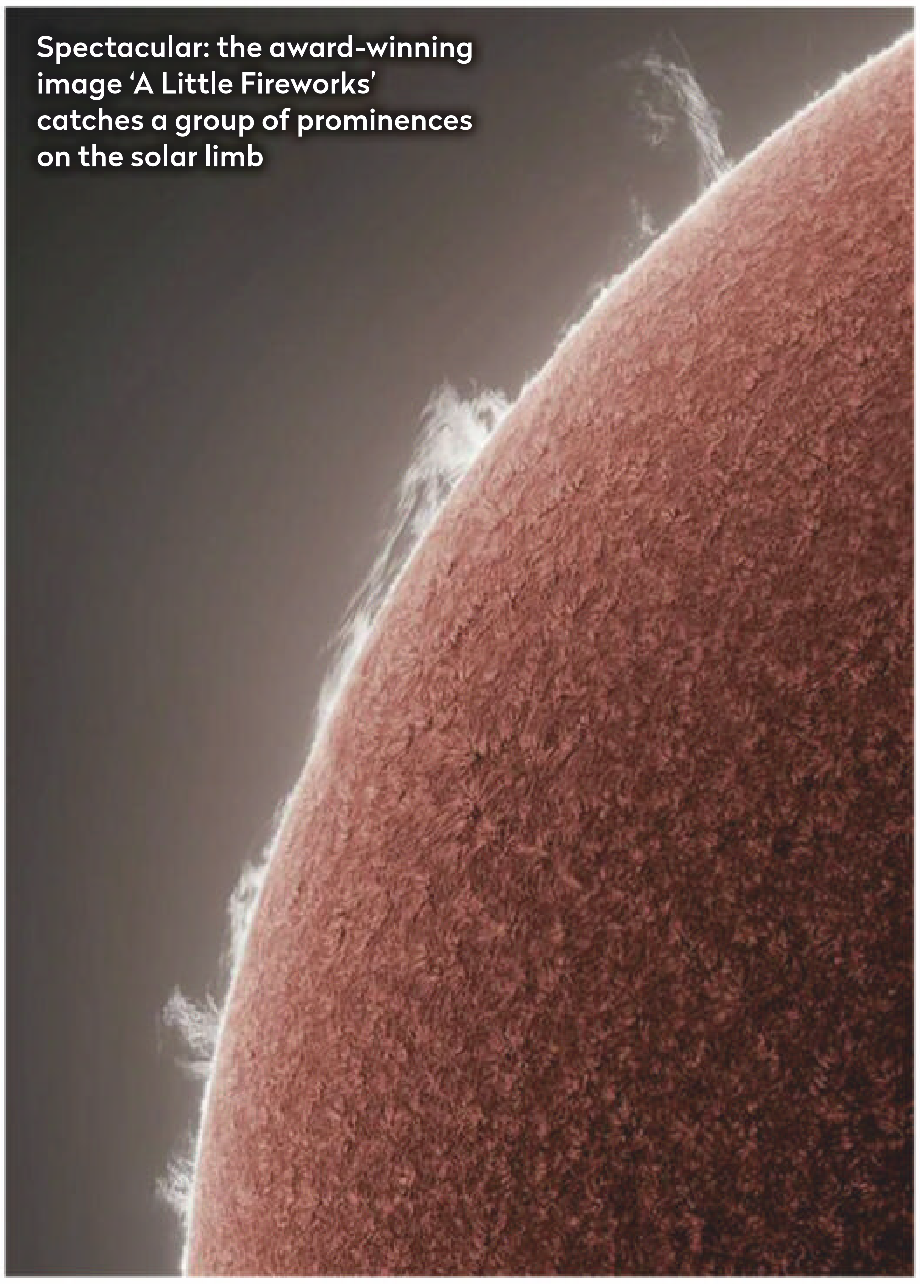
IIAPY Masterclass A standout image of the Sun

How to construct a stunning solar image by concentrating on activity at the Sun's edge

When will this all be over? We've all been asking the question during COVID-19, but it has also been on the minds of solar astrophotographers for an entirely different reason. Our Sun entered the depths of solar minimum back in 2018 and we are wondering when it will wake up. What can a solar photographer do when the Sun constantly shows a blank face?

Our answer is to look at the Sun's edge, while remembering to stay safe – never look at the Sun directly and always use solar filters on any equipment that is pointed towards it. Even on days when the disc is spotless, the limb often sports handsome prominences. These arcs of hydrogen plasma are photo-worthy subjects for any astronomer equipped with a hydrogen-alpha (Hα) filter. Using a 90mm Hα Coronado etalon filter mounted on a 92mm f/4.8 refractor gives us a versatile setup that can cover wide-field and closeup imaging. With a small black and white streaming camera we can shoot wide to capture the full solar disc or, by adding a Barlow lens, zoom in on specific activity.

On the day of the 'A Little Fireworks' capture, in July 2018, the prominences were spotted with the telescope and eyepiece, before switching to the camera to capture the frames for processing. We captured two sets of data, one for the prominences and one for the surface detail. As atmospheric turbulence was low, we were able to add a Barlow lens to increase the magnification, improving the view of the prominences. Critical sharp focus was attained with ease by using live view on a laptop screen.



Spectacular: the award-winning image 'A Little Fireworks' catches a group of prominences on the solar limb

We tuned the filter for brightness and detail, set gamma to low and turned the gain off. The capture duration was set for one minute, which yielded a stream of 1,800 individual frames. At this magnification, an active prominence can show movement over a short time, so it's important to plan the duration of capture so that movement does not result in any blurred detail after stacking.

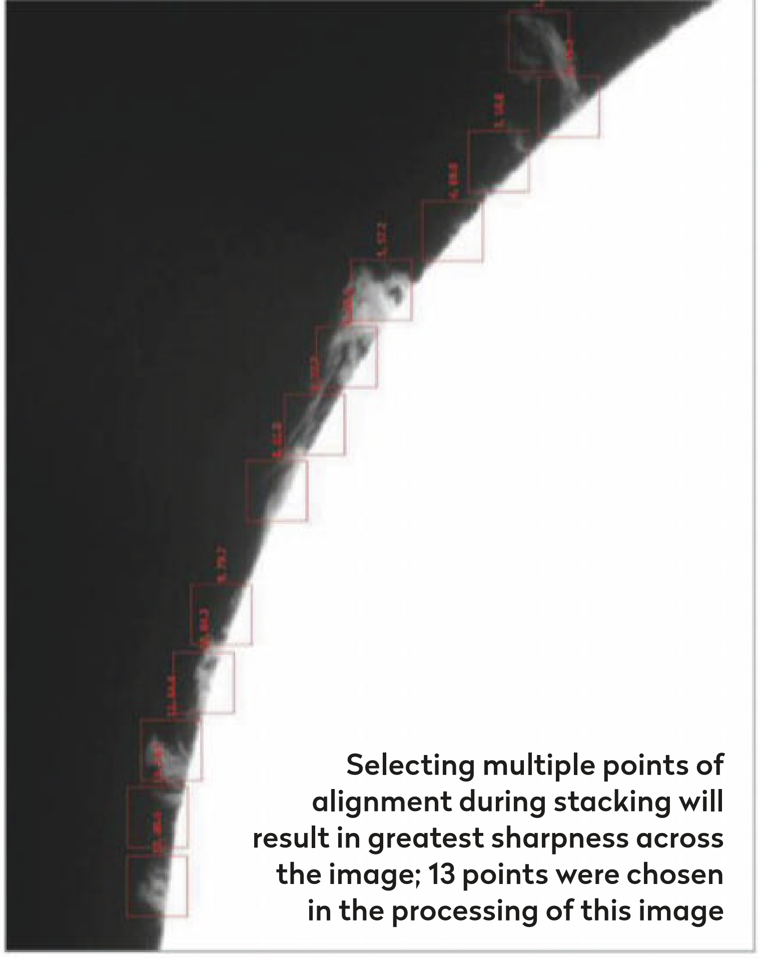
In the frame

Software such as RegiStax or AutoStakkert! can be used to analyse the stream of frames, sorting them from sharpest to blurriest. We selected the best 25 per cent, which were aligned and stacked ready for processing. Be sure to use multiple points (see image, opposite, top) when aligning the frames to maximise sharpness across the entire field of view. The resulting stack will provide a smooth image, allowing further processing to tease out the finest details.

Open the stacked image in Adobe Photoshop or your favourite image-processing software. Most dedicated astronomy image-processing programs will provide a sharpening tool so select this. Great attention should be paid to selecting settings that render additional detail but do not add artefacts.

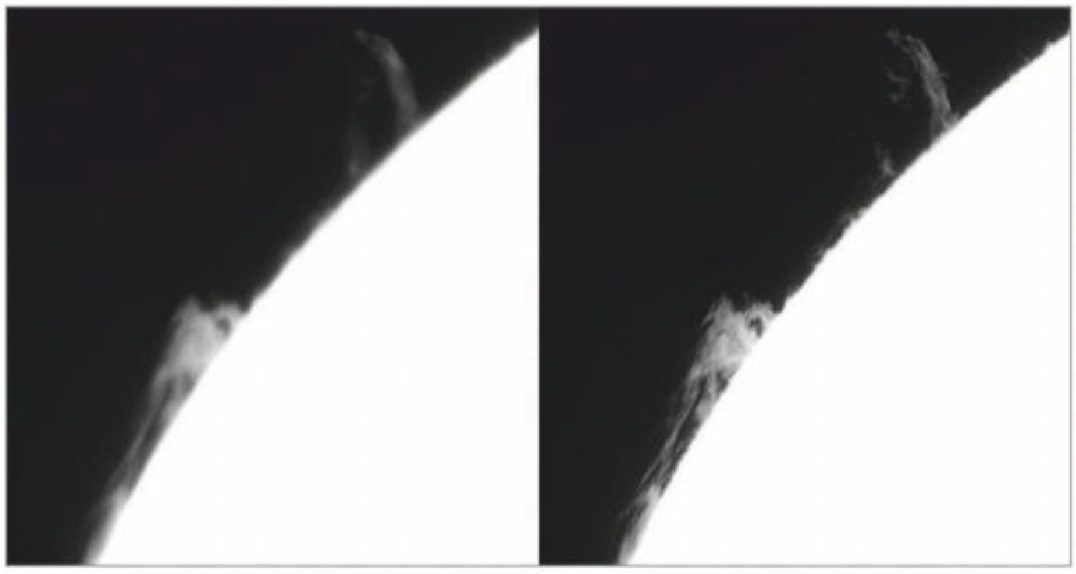
Insight Investment **Astronomy Photographer of the Year**
Advice from the 2019 winner of the 'Our Sun' category

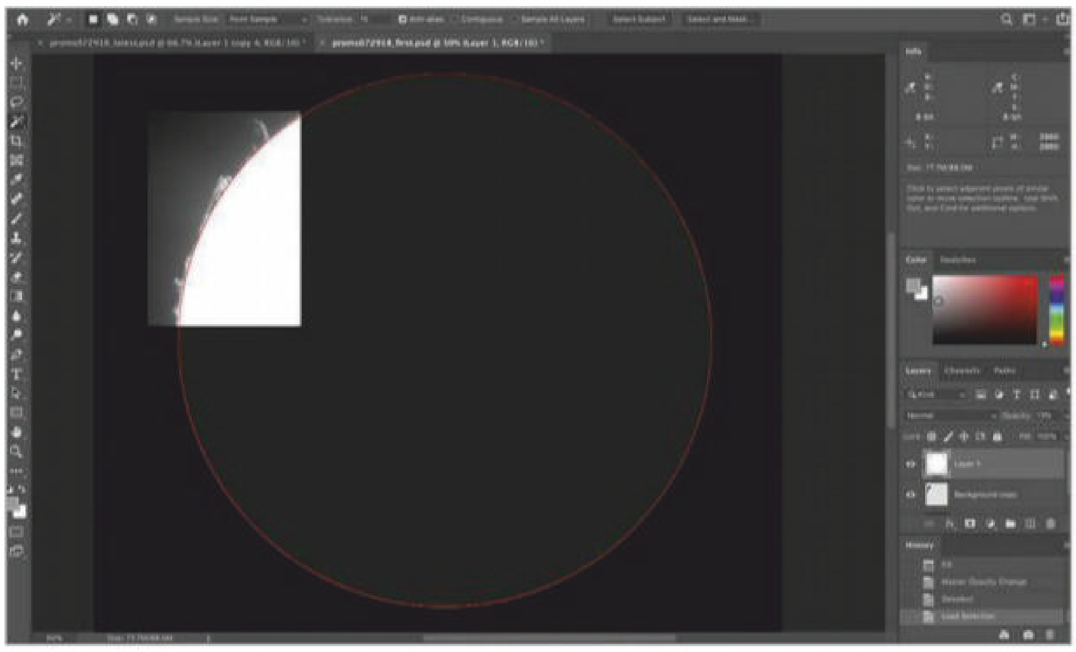
ALL PICTURES: ALAN FRIEDMAN



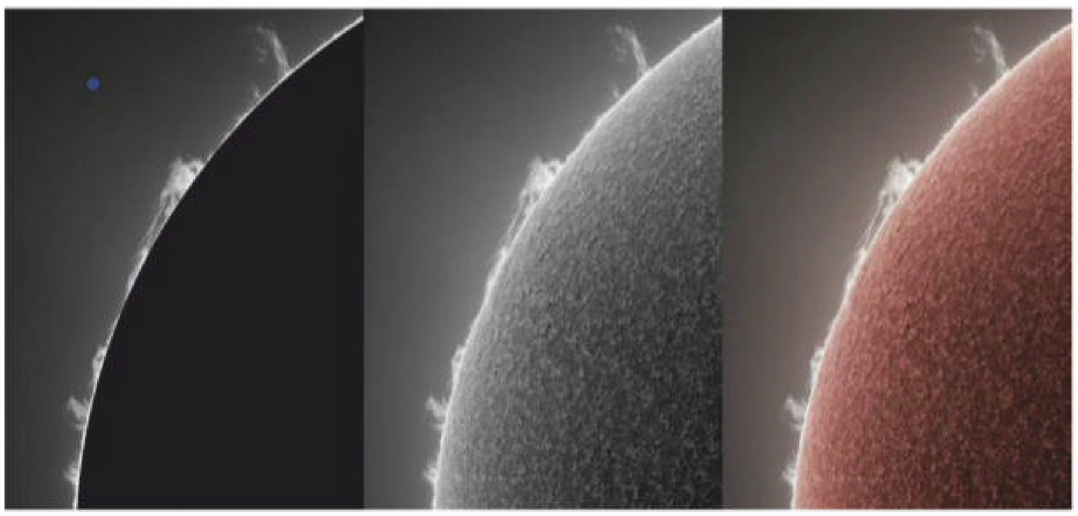
Selecting multiple points of alignment during stacking will result in greatest sharpness across the image; 13 points were chosen in the processing of this image

▼ Detail of the image following the stacking of individual frames – on the left, the stack as it appears before processing and on the right, following processing with an unsharp mask





▲ A screenshot showing how a circular disc the size of the Sun has been selected. We add a new layer and fill this selection in black to create the occulting disc



3 QUICK TIPS

1. Selecting numerous points and stacking multiple times for each region will yield a sharp result across the entire image.

2. Create a circular marquis the size of the Sun to add a black occulting disc to your image.

3. Use a light hand with an unsharp mask to reveal detail without adding artefacts.

Experiment with the settings; we find a small pixel radius (1.0 pixels or smaller) will provide a good result, improving sharpness without creating harsh edges and unrealistic contrast.

At this stage you can add a black occulting circle to mask the brilliant disc of the Sun. This will reduce glare and allow the faint extensions of the prominences to be seen clearly. Although you can use the Magic Wand tool, we find it much easier to use the Circular Marquis tool. Create a new layer and fill the circle in black to complete the occulting disc (see screenshot, below, left). Note the size of this circle in pixels: dividing this number by 109 yields the size of the Earth to scale. An Earth-sized circle added to the final picture can illustrate the size of a massive solar prominence (see the left variation in the bottom set of three images).

On the surface

If the observing session provides a good view of the surface of the Sun, this detail can be recorded and added to the final image. The surface is much brighter and requires different exposure settings than the fainter prominences. We again processed using multiple point alignment and an unsharp mask to reveal a sharply detailed view of the solar chromosphere. The disc detail is cut and pasted into a new layer above the original prominence image. There are many ways to process the layers for the final result (see the set of three examples, below left). Here we have inverted the tonality of the surface, which can add to the perception of depth and dimension in the swirls of the Sun's chromosphere. Layers for prominence and surface are colourised to enhance the final image.

Do keep an eye on the edge of the Sun. There is always something worthwhile to see and shoot. With practice, we will be in good shape to follow the curve of activity upwards and enjoy the Solar Maximum ahead.

Alan Friedman is an artist and astrophotographer who is based in Buffalo, New York. He won the 'Our Sun' category at the IIAPY in 2019 with 'A Little Fireworks'

◄ Three variations of image presentation: (left) the prominences with a black occulting disc and a blue circle to show Earth's size to scale; (middle) with added chromospheric detail; (right) the final result with colour

Your best photos submitted to the magazine this month

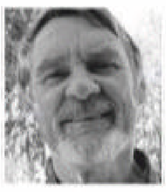
ASTROPHOTOGRAPHY GALLERY

More ONLINE
A gallery containing these and more of your images

PHOTO OF THE MONTH

△ NGC 3324

Shawn Nielsen and Russ Jacob, New South Wales, Australia, June 2019



Russ says: "This Hubble palette image of a Southern Hemisphere jewel, NGC 3324, was a collaboration: I collected the data and Shawn in Canada did the processing. Here in New South Wales I have Bortle 5 skies, which helps, and a 15-minute drive from my home I'm into Bortle 2."

Equipment: ZWO ASI 1600MM Pro mono camera, Sky-Watcher Black Diamond 200/1000 f/5 reflector, Sky-Watcher NEQ6 mount **Exposure:** 87 x 180" **Software:** SGPro, PixInsight

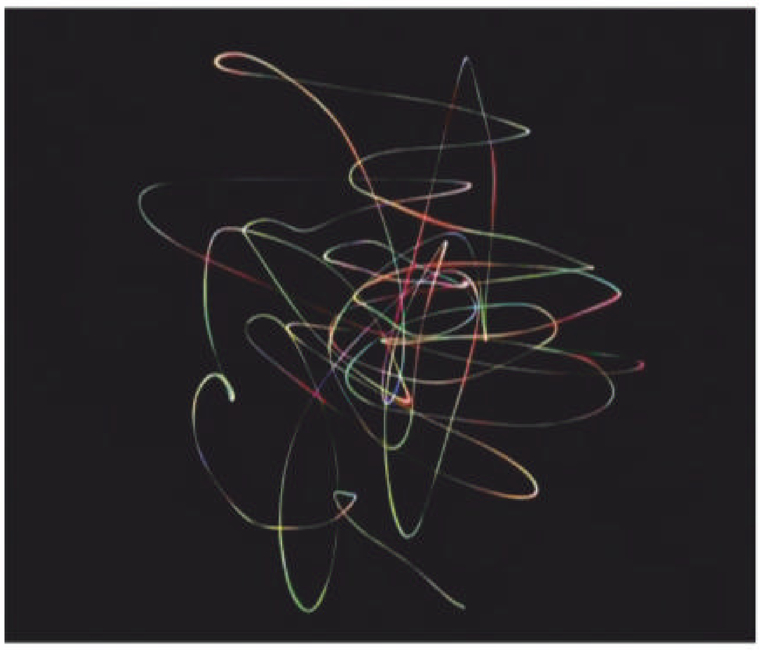
Shawn's top tips: "Russ has a good, dark night sky to collect the data from. While it's possible to do narrowband imaging from light-polluted areas, there is nothing better than a dark site. I used PixInsight for its precision set of tools and was pleased with the result. A collaboration like this gives an opportunity to see and work with data from different scopes, different cameras and different world locations, which would be unrealistic and perhaps unaffordable to do otherwise. It's also an opportunity to learn from each other, not only imaging techniques but processing too. And it's not uncommon to make a new friend out of it!"

Lyrids, Milky Way & airglow ▷

Tomáš Slovinský, Zbojská, Slovakia, 21 April 2020

Tomáš says: "Around the Lyrids peak I spent a whole night at the Muráň Plateau capturing meteors. After midnight a red airglow appeared and lit the sky, so I decided to make this 360° panorama."

Equipment: Canon 6D DSLR, Sigma 28mm Art lens, Samyang 12mm lens, Sky-Watcher Star Adventurer mount **Exposure:** Panorama: ISO 8000, f/2.2, 25", meteors: ISO 10000, f/2.8, 25" **Software:** Lightroom, Photoshop, PTGui, RegiStar

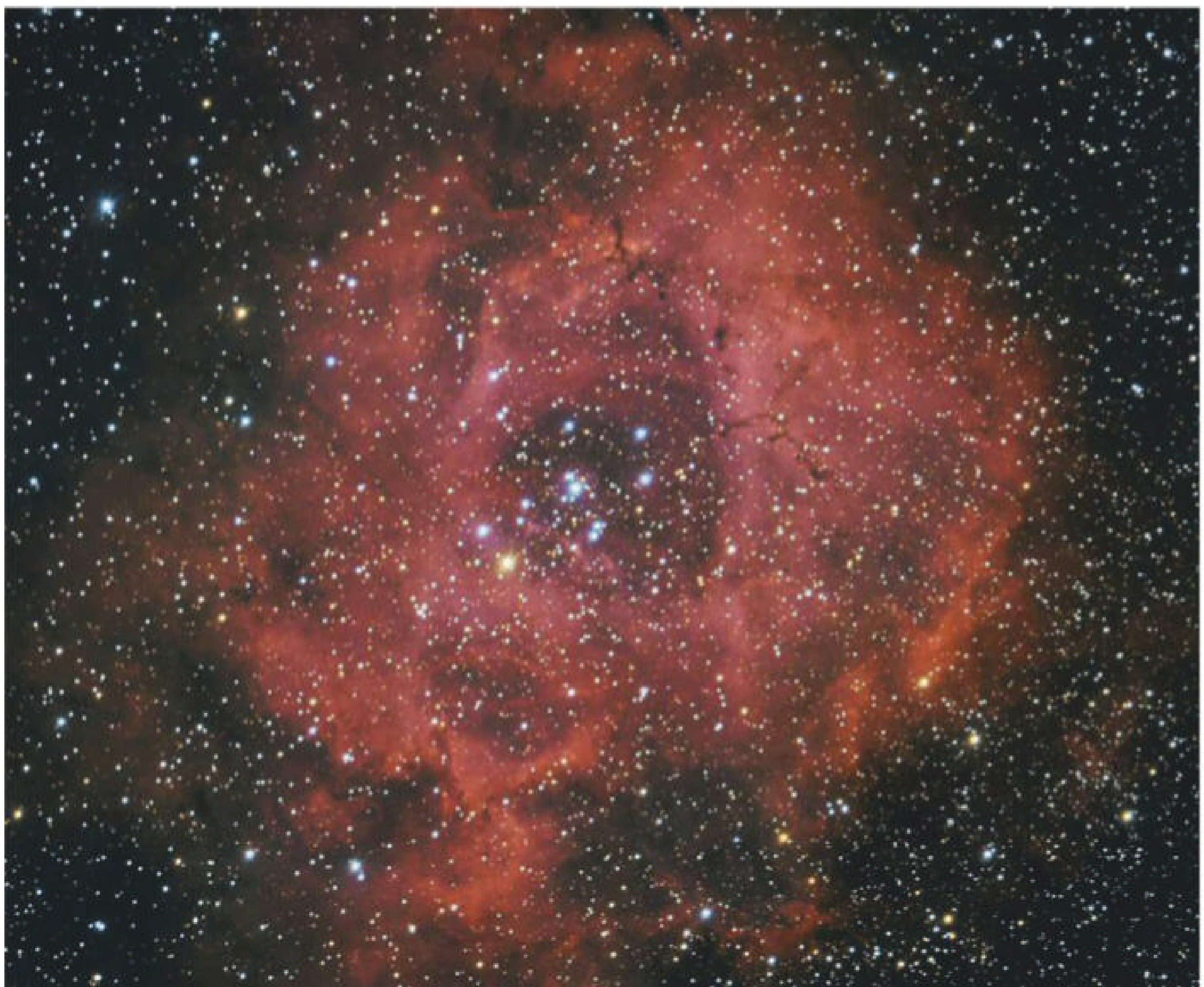


△ Sirius squiggles

Gifrin Stephen, Tamil Nadu, India, 27 April 2020

Gifrin says: "I wanted to capture all of the colours of Sirius in one picture and the long-exposure light trail method, made by deliberately swinging my camera, immediately came to mind. I was very pleased that I managed to capture as many colours as I did."

Equipment: Canon 200D DSLR **Exposure:** ISO 3200, f/5.6, 5" **Software:** Photoshop



◁ Rosette Nebula

Bob Bowers, Haverhill, Suffolk, 20 January 2020

Bob says: "This was a good target for me, directly to the east over open fields, where there are no light issues. As it's quite a large target I wanted to see how the field of view would be with my new Celestron RASA 8 and the Atik Horizon camera – and I was very pleased with the result. I think the challenge is to get the star colours right to show the prominent yellow star."

Equipment: Atik Horizon one-shot colour camera, Celestron 8-inch Rowe-Ackermann Schmidt astrograph, Sky-Watcher AZ-EQ6 Pro mount **Exposure:** 89 x 120" lights, 30 x 60" darks, 30 bias, 50 flats **Software:** AstroPixelProcessor, Photoshop

◁ Supermoon

Luis Rojas, Santiago de Chile, 7 April 2020

Luis says: "I took this from my balcony. The best 350 captures were selected using preprocessing procedures. The result: a full Moon with its colours, a perfectly spherical rock suspended in space."

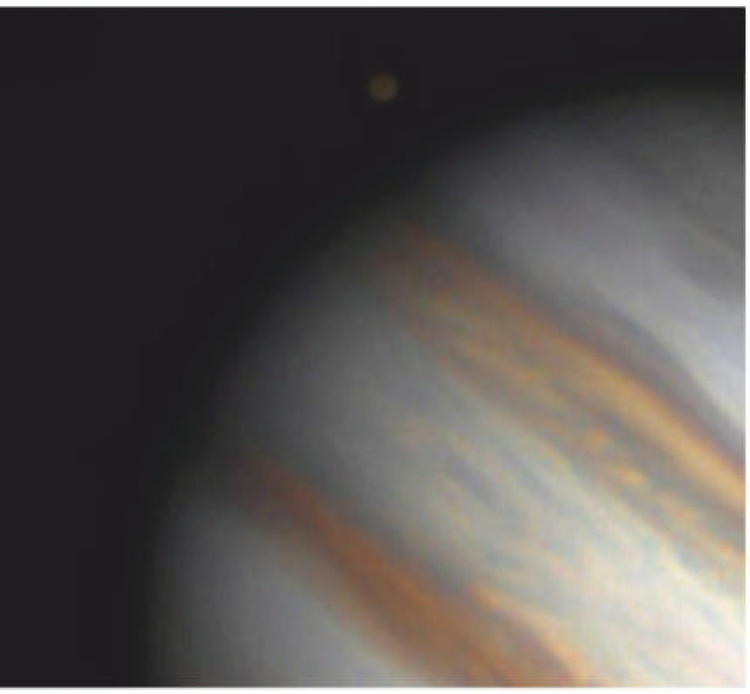
Equipment: Canon T6i DSLR, Explore Scientific ED102 triplet apo refractor, iOptron iEQ30 Pro mount **Exposure:** ISO 100, 1/500" x 350 **Software:** PIPP, RegiStax, Photoshop

Milky Way panorama ▷

Sally Eyre, Wellington, New Zealand, 28 April 2020

Sally says: "I took this manual panorama at around 4am one morning at Otari-Wilton's Bush in Wellington. It was just as New Zealand came into Level 3 COVID-19 lockdown and this nature reserve is within permitted walking distance from my house."

Equipment: Canon 6D Mark II DSLR, Manfrotto mount with panoramic head **Exposure:** ISO 800, 15" **Software:** Lightroom, MICE, Photoshop



◁ Ganymede

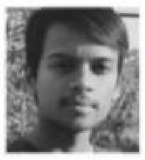
Fernando Menezes, São Paulo, Brazil, 26 April 2020

Fernando says: "This was the first time that I managed to capture some detail on Jupiter's moons. I processed the video focusing only on the moon, so the image of Jupiter itself doesn't come out very well, but I preferred to leave it like that."

Equipment: ZWO ASI 290MC camera, Meade LX200 10-inch, iOptron CEM60-EC mount **Exposure:** 13,233 frames **Software:** SharpCap, AutoStakkert!, RegiStax, Photoshop

◁ NGC 253

Utkarsh Mishra and Franck Jobard, Chile, October 2019




Utkarsh says: "I shot this remotely via Insight Observatory's link to the ATEO-3 scope at Deep Sky Chile, where data acquisition was done by Franck. The guide star was very dim, which was a challenge, but we were amazed by the luminance data we got from the galaxy and decided to shoot colour to make an LRGB version of it."

Equipment: Quasar 12.5-inch f/9 Ritchey-Chrétien
Exposure: 17 hours: RGB 1.5 hours each, L 68 x 15'
Software: TheSkyX, PixInsight, Photoshop

ISS pass ▷

Jonas Forsbäck Hedegaard, Skælskør, Denmark, 30 March 2020

Jonas says: "My goal was to get the International Space Station together with the Moon, Venus, the Pleiades, the Orion Nebula, Sirius and Rigel. Under the ISS you can see a line of satellites, which I believe is Starlink."

Equipment: Nikon D3400, Samyang 14mm f/2.8 lens, iOptron SkyTracker mount **Exposure:** ISO 1600; Sky: f/4, 160"; Foreground: f/2.8, 120" **Software:** Lightroom, Photoshop

ENTER TO WIN A PRIZE. HERE'S HOW:

Whether you're a seasoned astro-photographer or a beginner, we'd love to see your images. Email them to **contactus@skyatnightmagazine.com**. Ts&Cs: www.immediate.co.uk/terms-and-conditions

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a finder–guider adaptor, which connects T-thread guide cameras from ZWO, Orion and others to 9 x 50 standard finders from Sky-Watcher. The accessory comes with full instructions and support. **www.modernastronomy.com • 020 8763 9953**

SAVE UP TO 50%

on *BBC Sky at Night Magazine* special editions Plus FREE UK delivery* on all orders!

SALE

Experts from *BBC Sky at Night Magazine* show you how to make your own equipment from everyday objects with projects ranging from accessories, telescopes, solar observing, mounts and imaging.

Immerse yourself in the wonder of the night sky with this album of spectacular images taken by astrophotographers around the world, plus expert imaging tutorials covering the most popular targets.

Discover the story of over 50 years of manned space exploration in this lavish, 116-page special issue. With articles by leading spaceflight writers and rarely seen photos of astronauts and their spacecraft.

The Story of the Solar System traces the life of our Sun and explains how our planetary system came into existence, how it has evolved and how it might all end billions of years from now.

ORDER ONLINE

www.buysubscriptions.com/skysale

Or call our hotline: 03330 162 138† Please quote code: SKYSPEC

†Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. Lines are open 9am-5pm weekdays only. *Free delivery on UK orders only. Overseas postage prices vary by product and country, for more details check www.buysubscriptions.com/skysale. Please allow up to 21 days for delivery. Offer ends 15 July 2020. All orders subject to availability.

The best in equipment, accessories and books each month

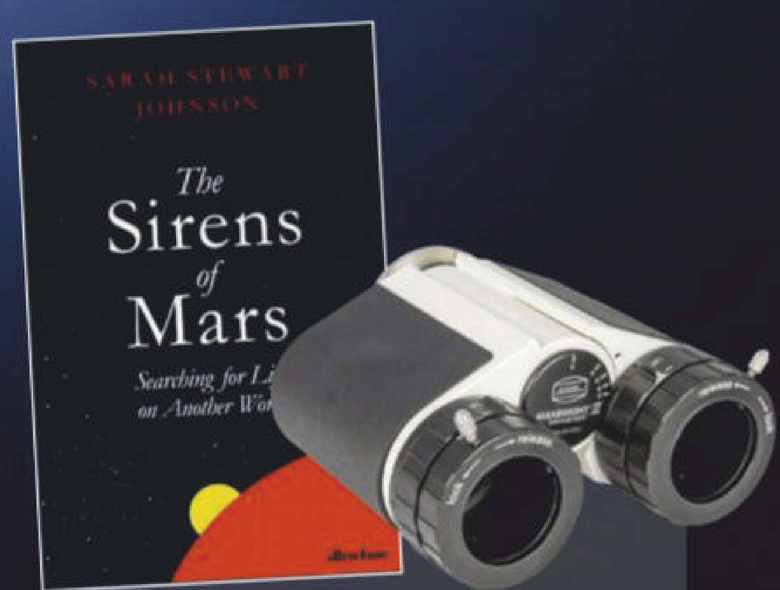
REVIEWS

SUBSCRIBE
Discover the best new kit each month

Find out more about how we test equipment at
www.skyatnightmagazine.com/scoring-categories

@THESHED/PHOTOSTUDIO

78 Discover how the Unistellar eVscope manages to deliver the deep-sky views of larger telescopes



PLUS: Books on searching for life on Mars and how to image the Moon, plus a roundup of the latest must-have gear

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good ★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Unistellar eVscope

A user-friendly, compact smart telescope that delivers stunning deep-sky colour views

WORDS: PAUL MONEY

VITAL STATS

- **Price** £2,599 (+ £59 shipping)
- **Optics** 114mm (4.5-inch) reflector
- **Focal length** 450mm, f/4
- **Sensor** Sony Exmor IMX224
- **Mount** Motorised single arm, altaz, Go-To
- **Power** In-built lithium-ion rechargeable (9-hour) battery
- **Tripod** Aluminium, adjustable height
- **Ports** USB-C (for power) and USB-A for charging smartphone
- **App control** Unistellar app for smart phones
- **Weight** 9kg
- **Supplier** Unistellar SAS
- **Email** contact@unistellaroptics.com
- **https://unistellaroptics.com**

We have reviewed many small telescopes in *Sky at Night Magazine* and have often added the proviso that you have to keep visual expectations low. Unfortunately, small scopes don't have a great deal of light grasp and will not produce detailed images like those often found on their nicely designed boxes. The Unistellar eVscope challenges that view, while perhaps giving an insight into the future of visual astronomy. The telescope was developed as a user-friendly system – by Unistellar in association with the SETI Institute – to be used for citizen science projects, so we were eager to check it out.

Essentially, the eVscope marries a Sony IMX224 sensor with a 4.5-inch, f/4 reflector and an electronic eyepiece, alongside cutting-edge electronics and computing. The telescope tube sits on a single-arm computerised altaz mount attached to a sturdy, adjustable height tripod. Although the eVscope looks neat, the eyepiece seems unusually placed when compared with standard reflectors. Its position, however, creates a more comfortable viewing position and experience; instead of collecting light from a secondary mirror, the eyepiece receives the signal electronically, meaning it doesn't have to be placed higher up the tube. The spider vane at the top of the tube holds the Sony sensor at the point where light, having travelled down the tube to the mirror, is focused directly directly back at it. The data is processed on board in the mount and then sent to the eyepiece, which delivers impressive colour results. We found that stars, for example, showed up as particularly colourful, while comets showed a definite greenish hue.

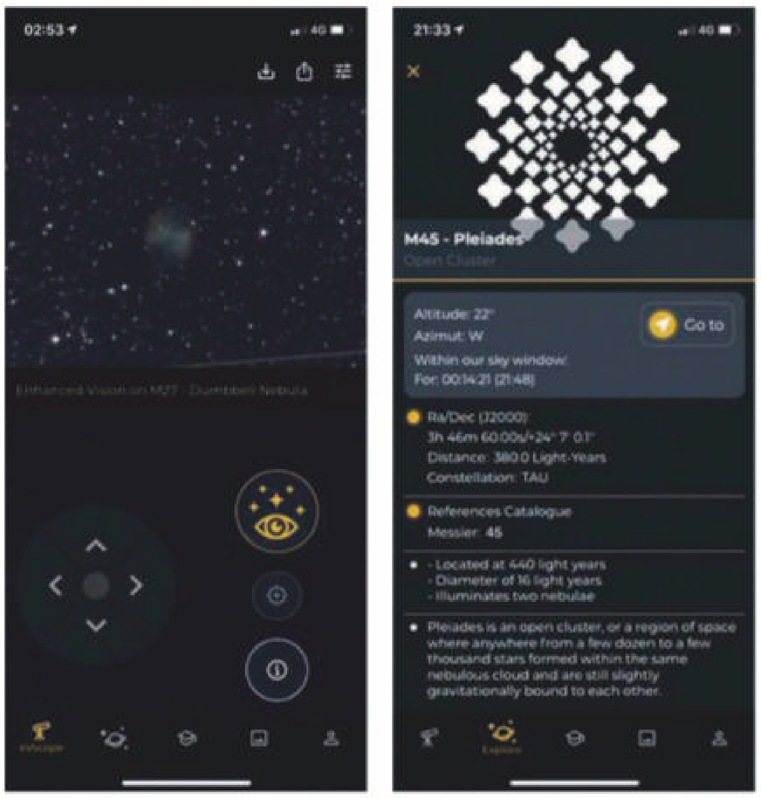
This is what makes the eVscope system stand out. Normal 4.5-inch (115mm) reflectors show galaxies and nebulae as pale imitations of their true nature and can often disappoint, whereas the eVscope builds up a live image in colour using live stacking and registration. Galaxies and nebulous targets, including those that would normally be considered too faint for such an ▸

Easy to control app

At the heart of the eVscope is the all-important Unistellar app that controls every aspect of the telescope with the touch of a finger. The mount sets up a Wi-Fi network and you join it with your smartphone. The app then recognises the scope and works out where it's pointing by automatically plate solving the star field. Once done, it confirms the Go-To function, and live view is activated so you can tap on the explore tab to chose from the suggested targets.

The initial view may appear quite dim with no sign of the object, but you can tap to activate an 'Enhanced Vision' mode and very quickly the view is transformed both in the eyepiece and on screen. You can make manual adjustments to improve the view and then save the image to your phone's photos and also share later with the citizen science project.

There is more to explore in the app, including an option to input coordinates to find targets not in the suggested list. It's easy to lose yourself exploring them, forgetting you are using a small telescope.



▲ The Unistellar app can be set for 'Enhanced Vision' of a target (left); and to access factual information (right)

ALL PHOTOS: @THESHED/PHOTOSTUDIO

SCALE

Optical tube

The mirror and sensor are housed in a tube 65cm long and 23cm wide, the latter including the mounting arm near the base. The electronic eyepiece can be focused and lies low down the tube, giving easy access and a comfortable viewing experience.

Optics

The design incorporates a 114mm (4.5-inch) diameter mirror with a focal length of 450mm, which gives a focal ratio of f/4. At the front end, the spider vane (which normally holds a secondary mirror) holds the Sony Exmor IMX224 imaging sensor.

Mount

The mount is integrated into the optical tube and houses the onboard computer, altaz motors and the lithium-ion rechargeable battery. On the side is an on/off touch button which lights up red when powered up, and underneath are two USB ports: one for charging and another for powering a smartphone.

Tripod

The black, aluminium tripod is specifically designed for the Unistellar eVscope and is sturdy with plenty of adjustment to position the eyepiece at a good height for comfortable viewing. It also contains a bubble level to ensure an accurate setup and alignment.

> **KIT TO ADD**
> **1.** eVscope backpack
> **2.** Zoom app: to share the experience
> **3.** ClearOutside app: to see if it's worth setting up

▸ aperture, are revealed in detail as you watch through the eyepiece. For example, we were able to view and image Comet Atlas, which had started to disintegrate and was no longer visible in a 10-inch (250mm) reflector.

Once the telescope is powered up you can connect and control it via the Unistellar app, which is available for iOS and Android smartphones (but not for tablets at the time of writing). The telescope generates its own Wi-Fi network which you connect to, allowing control of the eVscope. It then automatically images the field of view and identifies where it's pointing by plate solving a database of several million stars. We found it useful to use the virtual joystick on the app to point roughly at 45° to the horizon as it seemed to improve the accuracy of the initial pointing. Once it has finished initialising and identifying the star field it is ready for you to choose your target from the explore tab of the app.

Delivering the goods

We took a tour of the suggested targets, ranging from Venus to galaxies (including M81 and M82, M65 and M66), globular clusters M5 and M13, the Beehive Cluster M44 and later in the night the Ring Nebula and Veil Nebula among many others. One thing to note is that the eVscope's field of view is 30 arcminutes, so although you can just about fit the Moon in the view, large targets such as the Pleiades and the Andromeda Galaxy are only partly viewable. There are lots of targets to choose from, however, and we were able to view and image Comet Atlas at a time when others could not view it with larger instruments. To see these targets slowly appearing in colour in both the eyepiece and smartphone view was a revelation.

The eVscope is certainly an amazing step forward and requires so little effort from the user that anyone can use it. That ease of use does come at a price, however, which may put some observers off.

Accessories

A front cover dust cap helps protect the tube and mirror from unwanted dust, which can otherwise decrease performance. The dust cap also contains a surprise – a detachable Bahtinov mask to help with focusing. The eyepiece has a rubber plug-in dust cap to protect it while the eVscope is not in use.

VERDICT

Assembly	★★★★★
Build & Design	★★★★★
Ease of use	★★★★★
Features	★★★★☆
Optics	★★★★☆
OVERALL	★★★★½

@THESHED/PHOTOSTUDIO, PAUL MONEY

Altair GPCAM2 327C video astronomy camera

A simple to use, all round astronomy camera that can move swiftly between targets

WORDS: TIM JARDINE

VITAL STATS

- **Price** £269.50
- **Sensor** Sony IMX327 STARVIS BSI
- **Camera type** Colour
- **Size** 70mm x 39mm diameter
- **Weight** 70g
- **Supplier** Altair Astro
- **Tel** 01263 731505
- **www.** altairastro.com

ALL PICTURES: @THESHED/PHOTOSTUDIO

Altair Astro's family of GPCAM astronomy cameras have a good reputation among astronomers, for being easy to use and producing good quality images. Building on this foundation, Altair has introduced the GPCAM2 327C. It's a one shot colour (OSC) camera that offers increased sensitivity over its predecessors. The simplicity of the GPCAM2 327C, both to set up and to use, makes it perfect for getting the best out of clear-sky opportunities. Once the camera drivers are downloaded and installed, it simply plugs in and is recognised immediately by the software, so you slew the telescope to your desired target, set the exposure length and gain to what you want, and just enjoy the view.

This type of camera is especially suitable for electronically assisted astronomy (EAA) with live video, and as luck would have it a perfect target emerged in the shape of Comet C/2019 Y4 (ATLAS). Even in pristine skies it can be difficult to observe much detail in faint comets, and under the suburban conditions surrounding our observatory, this one at mag. +8.0 was a little underwhelming.

However, with the eyepiece swapped for the GPCAM2 327C, the view was quite different. Almost immediately we could see more of the glow around the comet, and with live image stacking, the direction and speed of travel – and some evidence of a tail – could be seen on screen from the comfort of our warm room. We found that we spent longer observing each target than we would using an eyepiece, and this resulted in a closer connection to the night sky, with the live view contributing to the feeling of 'seeing it with your own eyes'. Having the live image available on a laptop or computer screen makes it much easier to share the viewing experience with others, including children or observers who may struggle to identify the target object in an eyepiece.

Wealth of colours

We enjoyed visiting a wealth of globular clusters available in spring and noted that the colour camera was particularly good for highlighting the different types of stars, showing the red and orange colours well and contrasting them with younger blue ones. The great cluster in Hercules, M13, was particularly impressive, filling the frame with our 1m focal length telescope. ▸

Advanced sensor

At the heart of the GPCAM2 327C is an advanced CMOS imaging sensor from Sony Semiconductors. The Sony IMX327 STARVIS sensor offers increased sensitivity over the already impressive IMX290 sensors used in previous versions of the GPCAM, along with low dark current noise characteristics.

The 2.9micron pixels are arrayed in 1920x1080 format, and at full resolution, in 12-bit mode, speeds of up to 18 frames per second (fps) can be achieved on a suitable computer. However, by decreasing this resolution to 640x480, and 8 bits, we got up to 40fps, while using the region of interest (ROI) setting to reduce the resolution further to enable speeds nearing 60fps.

We were particularly impressed by the low noise (and few unwanted artefacts) from the camera's sensor, and the natural colour reproduction with minimal processing, which served to add to the feeling of 'proper observing'. By keeping the gain setting low, amp glow is nicely controlled, limited to one corner of the frame, and easily dealt with using dark frames. With that in mind a useful push-in silicon end cap is provided for capturing dark frames.

SCALE

USB 2.0

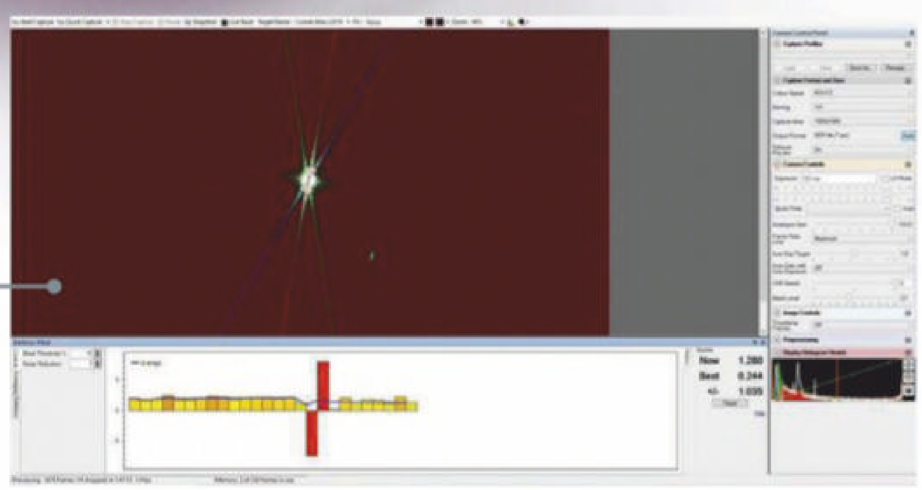
The camera has a standard USB 2.0 connection, favoured by astronomers for its stability, compatibility with existing equipment and the option to extend the cable runs. The 2m cable provided with the camera is good quality and has a right-angled plug which helps keep things tidy.

Guide port

In addition to the USB connection, the GPCAM2 327C can be linked directly to a compatible mount or auto-guider control using the 1.5m ST4 cable and socket provided. The high sensitivity and low noise characteristics befit a very capable guide camera. It is fully compatible with PHD2 scope guiding software.

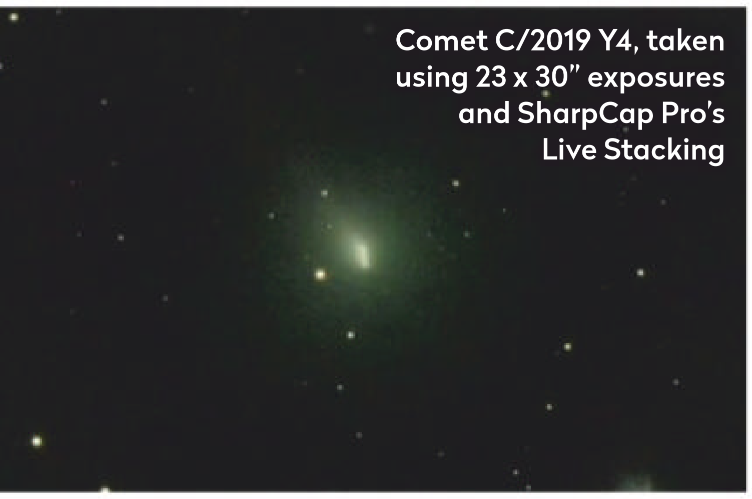
Dimensions and weight

Approximately the same size and weight as a standard Plössl eyepiece, the GPCAM2 327C is completely portable, and requires no additional cables or power supply other than the USB connection. It drops neatly into a standard 1.25-inch fitting, while the nicely machined fins on the camera housing help to dissipate heat.

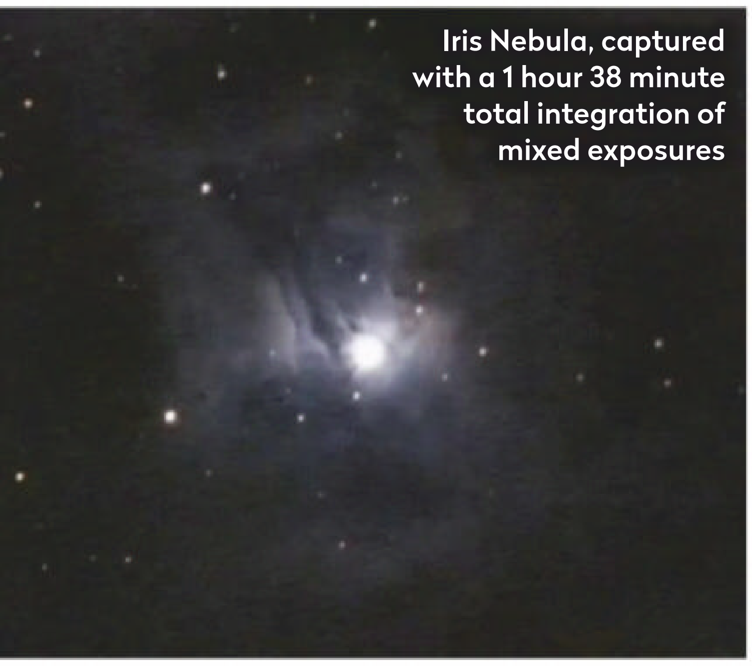


Software options

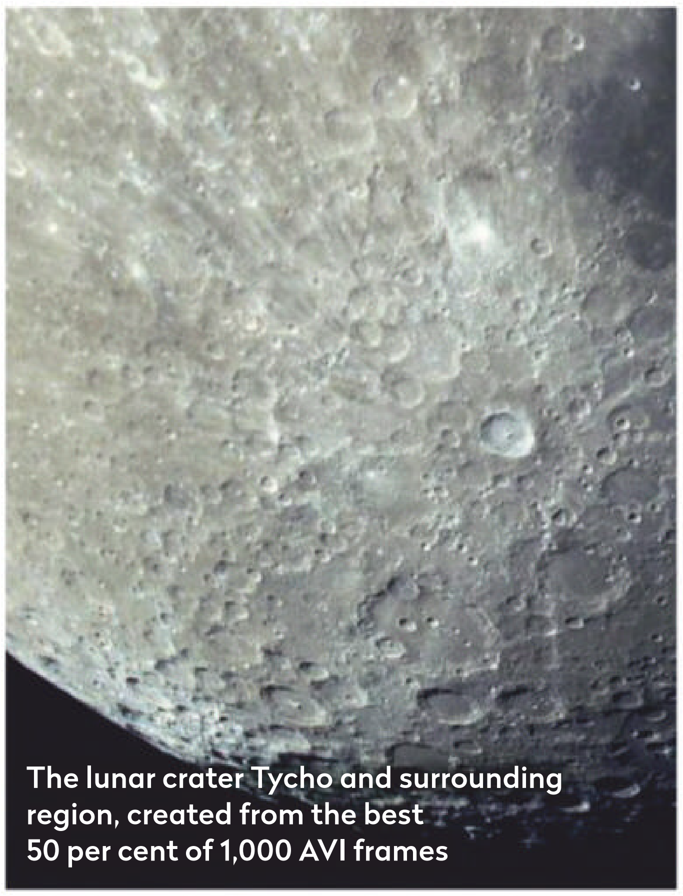
In addition to the intuitive and easy-to-use AltairCapture software, the camera comes with a 12-month licence for SharpCap Pro. This capable piece of software adds extra functionality to the camera; including assisted Bahtinov mask and other focusing techniques, polar alignment and detailed control of imaging runs.



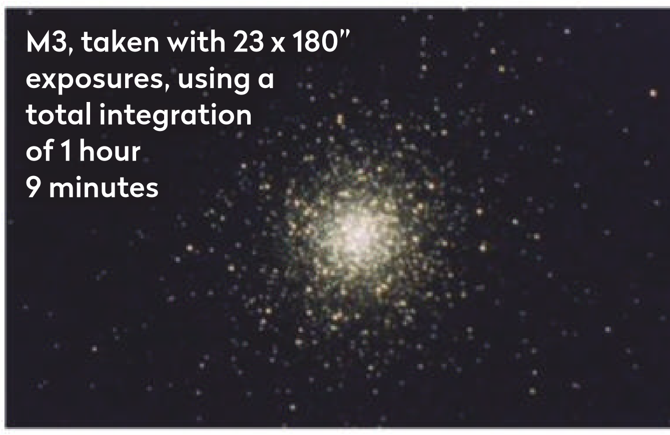
Comet C/2019 Y4, taken using 23 x 30" exposures and SharpCap Pro's Live Stacking



Iris Nebula, captured with a 1 hour 38 minute total integration of mixed exposures



The lunar crater Tycho and surrounding region, created from the best 50 per cent of 1,000 AVI frames



M3, taken with 23 x 180" exposures, using a total integration of 1 hour 9 minutes

M63, taken with 33 x 180" exposures and a total integration of 1 hour 39 minutes

▲ All the images (above) are captured with the Altair GPCAM2 327C camera through a Sky-Watcher Esprit 150 ED refractor

KIT TO ADD

1. Altair GPCAM Canon EOS lens adaptor for a dovetail bar

2. Altair QuadBand filter for city imaging with CMOS cameras

3. Altair 3x Premium Flat Field Barlow lens

▸ On fainter galaxy targets, the GPCAM2 proved really useful; where we would normally just be observing a bit of a smudge in our skies, some real detail came through, from the 'bruise' on the Black Eye Galaxy, M64, to the swirling dust clouds around the Sunflower Galaxy, M63. By increasing the exposure time to 60 seconds and taking a series of images, we were able to take some very detailed photos. In fact, reviewing our images folder revealed that we had enjoyed a bit of an imaging marathon, having acquired a diverse range of multiple targets: including globular cluster M3, open cluster M52, planetary nebulae NGC 6543, the Whirlpool Galaxy, M51 and the Iris Nebula, NGC 7023. The ease and speed of adjusting the camera settings to suit each target meant more time is spent capturing images, and less time fiddling with settings.

The versatility of the GPCAM2 327C impressed us. After taking images of fainter objects, we turned to a bright 85%-lit waxing gibbous Moon and were able to record an AVI video file instead of individual images – a technique which can also be used for imaging planets. Using the full bit-depth and resolution of the camera led to a very large file size, over 4.5GB for just under a minute, but the range of shades – from the blacks of the shadows to the white sunlit crater walls – produced a colour image that was neither under, nor over-exposed.

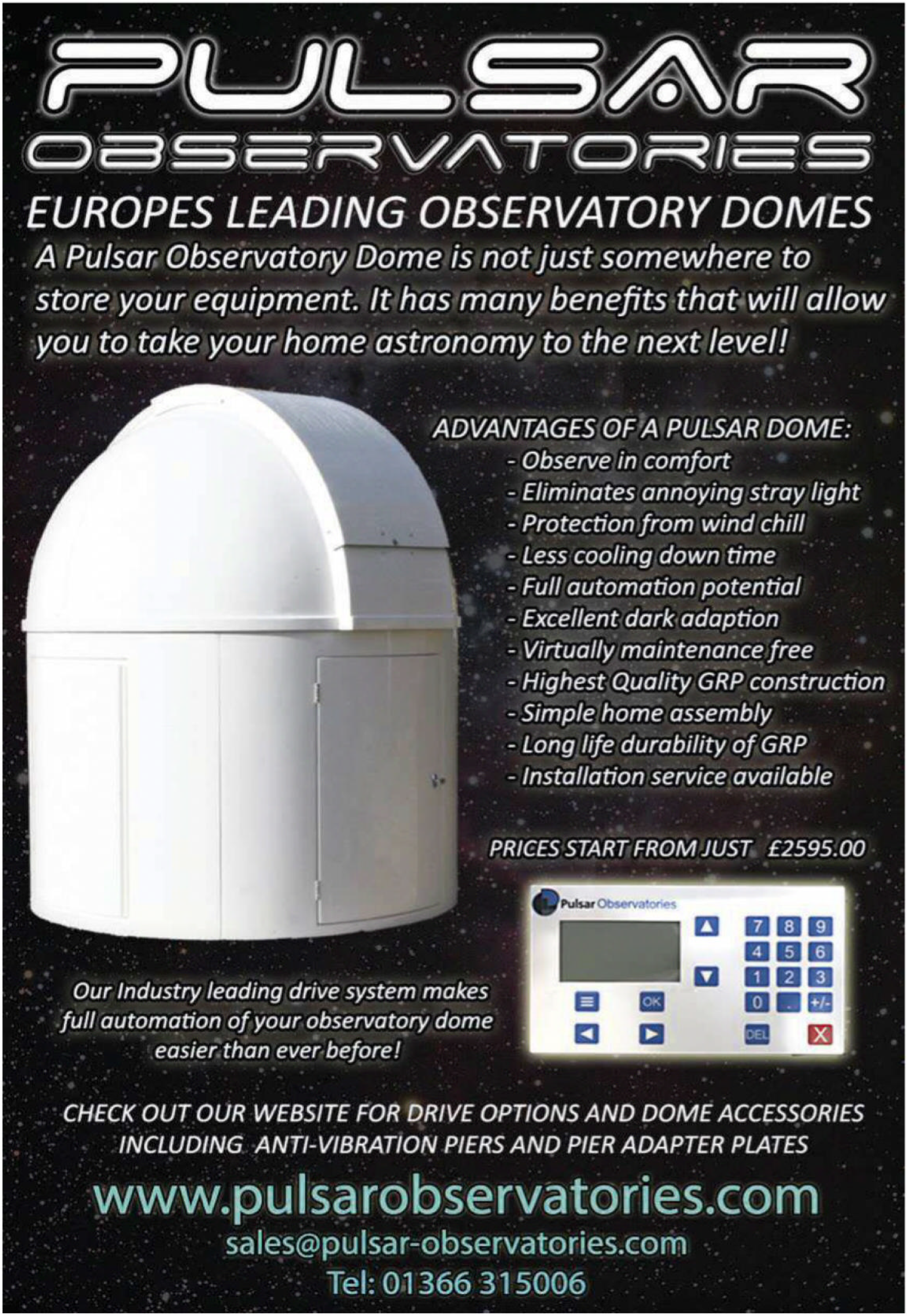
All in all, the GPCAM2 327C is a highly versatile, simple to use, all round astronomy camera, offering great results and value for money.

CS lens mount options

Adding to the already impressive list of uses for the camera, a separately available 120° lens can be attached, making an effective all-sky meteor camera. There is also a 1.25-inch nosepiece included which accepts regular filters. The camera is supplied with an IR/UV cut filter.

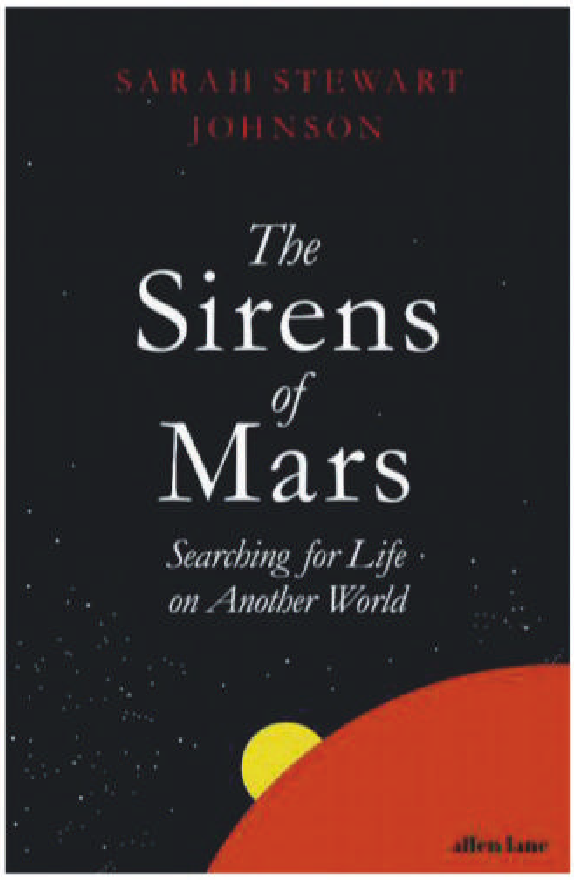
VERDICT

Build & Design	★★★★★
Connectivity	★★★★★
Ease of Use	★★★★☆
Features	★★★★☆
Imaging Quality	★★★★☆
OVERALL	★★★★☆


PULSAR
OBSERVATORIES
EUROPES LEADING OBSERVATORY DOMES
A Pulsar Observatory Dome is not just somewhere to store your equipment. It has many benefits that will allow you to take your home astronomy to the next level!
ADVANTAGES OF A PULSAR DOME:
- Observe in comfort
- Eliminates annoying stray light
- Protection from wind chill
- Less cooling down time
- Full automation potential
- Excellent dark adaption
- Virtually maintenance free
- Highest Quality GRP construction
- Simple home assembly
- Long life durability of GRP
- Installation service available
PRICES START FROM JUST £2595.00
Pulsar Observatories
Our Industry leading drive system makes full automation of your observatory dome easier than ever before!
CHECK OUT OUR WEBSITE FOR DRIVE OPTIONS AND DOME ACCESSORIES INCLUDING ANTI-VIBRATION PIERS AND PIER ADAPTER PLATES
www.pulsarobservatories.com
sales@pulsar-observatories.com
Tel: 01366 315006

New astronomy and space titles reviewed

BOOKS



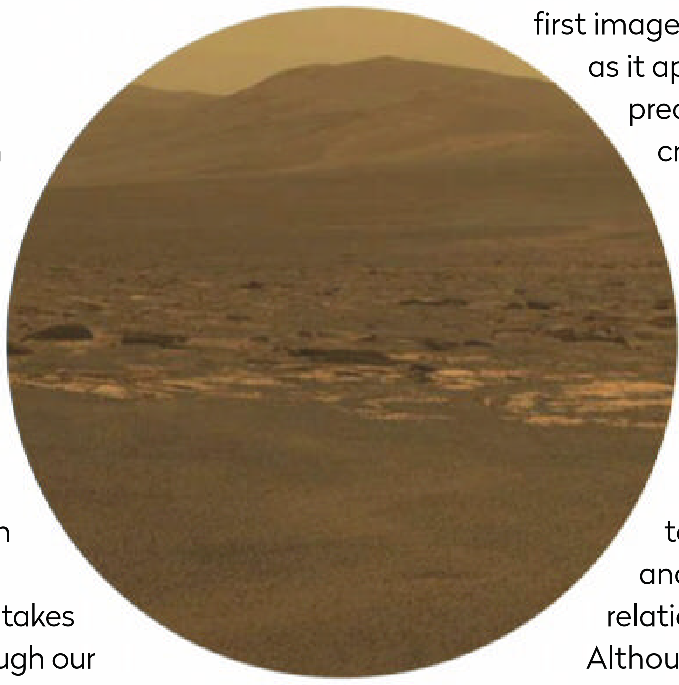
The Sirens of Mars

Sarah Stewart Johnson
Allen Lane
£20 ● HB

Surely there is life on Mars – or at least that is what was thought by astronomers from the late 1600s all the way up to the 1980s. But in recent years that statement has taken on a whole new meaning. This book takes us on a voyage through our relationship with the Red Planet and makes us appreciate the tremendous journey it has made in the popular zeitgeist, from a world covered in carefully engineered canals for advanced alien inhabitants, to a lush vegetated haven and finally to the cold, ancient and desolate wasteland we know today.

Looking behind the scenes of life as a modern planetary scientist, *The Sirens of Mars* follows the author's experiences of the lows and highs of many of the most celebrated Mars missions. The linear timeline of exploration helps to anchor Sarah Stewart Johnson's story to the big question of "Is there life on Mars?". We follow along with her as she realises the implications of highly acidic material uncovered by Opportunity, sit with her in the Mojave Desert mapping the landscape of alien terrain on Earth, and sympathise with the feeling of isolation and separation from the world as she adjusts to 'Martian time' in the control room at NASA's Jet Propulsion Laboratory, monitoring rovers on a distant world.

In many places you will rush to the internet to look up the images and maps described in the book to understand Johnson's wonder at the discoveries being made. The book would have greatly benefited from including some of these: the original pictures and charts of Mars used to design the Mariner missions that now sit on the author's office wall, the first image from Opportunity as it approached the precipice of Endurance crater, the Olympic Rings etched forever into the Martian rock by the Spirit rover. Some are easy to find and some impossible, but each is pivotal to the author's, and the reader's, relationship with Mars. Although at times not the easiest to follow, this is a must-read for fans of our Martian neighbour and humanity's longstanding search for life elsewhere in the Universe. ★★★★☆


▲ The rim of Endurance Crater looms into view as the Opportunity rover approaches

NASA/JPL-CALTECH/CORNELL/ASU

***Dr Hannah Wakeford** is an astrophysicist at the University of Bristol where she studies exoplanets using the Hubble Space Telescope*

Interview with the author
Sarah Stewart Johnson

Why is Mars such a promising place to look for life?

Around the time life was getting started here, Mars was also warm and wet, at least episodically, with streams and lakes and perhaps a deep northern ocean. There was a thicker atmosphere, a protective magnetic field and abundant sources of energy. It also had all the right chemical elements and organic building blocks for life. But what excites me most is the idea of a separate genesis on Mars – we could find a kind of life that's totally unlike life as we know it here on Earth.

Are we close to humans going to Mars?

The leap from never having been to space in 1957, when Sputnik launched, to landing on the Moon in 1969 seems to be a much harder leap than what it would take to go from our current capabilities to a human Mars landing. I don't know what the coming years will bring, but the stage is set for rapid progress if we decide we want to do it.

If a human mission to Mars was launching tomorrow, would you go?

I spent most of my twenties hoping to apply to NASA's astronaut program. Had the opportunity presented itself, I wouldn't have hesitated. But I now have two little kids and Mars would be too long a journey. The Moon would be like a business trip – three days there, three days back – but, with current technology, Mars would be a two-and-a-half-year endeavour: six months' each way plus a year and a half waiting for the planets to realign. I couldn't bear such a long separation.

***Sarah Stewart Johnson** is a planetary scientist at Georgetown University who's worked on NASA's Spirit, Opportunity and Curiosity rovers*

The Moon

IMAGING MUST-READ

James Harrop
White Owl
£25 ● HB

If you are a beginner to lunar observing and imaging, the learning curve can feel insurmountable. There is a surprising lack of coherent information on the subject and what there is may be fragmented and spread across many different sources. *The Moon* fills this gap in the market; it covers all aspects of lunar photography but also includes a lunar features observing guide.

The first part of the book deals with lunar photography. It includes equipment needed (from mobile phones through to CMOS cameras) and takes a look at photography techniques, image stacking, stitching and processing. The second part is a comprehensive guide to lunar features and how to observe them. The information is detailed yet easy to follow, and there are photographs throughout which are a huge help to the reader. One chapter, for example, features uncropped comparison photos of the Moon captured with a variety of camera lenses and different-sized telescopes. Later, there are useful screenshots to illustrate each step involved when image stacking, stitching and processing.

In one chapter the term 'eye piece projection' is used incorrectly to describe afocal photography with a smartphone, but it's correct elsewhere.

This book is a must-have for anybody interested in lunar photography. If you are a beginner, this is the only lunar observing book you will ever need, but even experienced observers will learn something from it and will wish this book had existed years ago. ★★★★★

***Mary McIntyre** is an outreach astronomer and teacher of astrophotography*

How to Die In Space

Paul Sutter
Pegasus
£20 ● HB

Working out how to die in space might seem easy – just take off the space helmet – but such trivial solutions are dealt with in the first few pages of this book. After that, the engineering and technological realities of space travel are dispensed with, and *How to Die in Space* takes us on a tour of the Solar System, then the Galaxy, then the rest of Universe.

Describing phenomena in astronomy normally relies on an abundance of analogy and metaphor. The metaphors are crammed in here, rushing to get off the pages and into your head.

Once you've got used to the style and tone, it feels very much like the author is speaking to you (and sometimes even insulting you). If it were a real conversation, though, I'd probably be rather exhausted just from listening and keeping up with the pace. The use of so many analogies – not to mention all the asides – in quick succession (sometimes simultaneously) can be quite tough going.

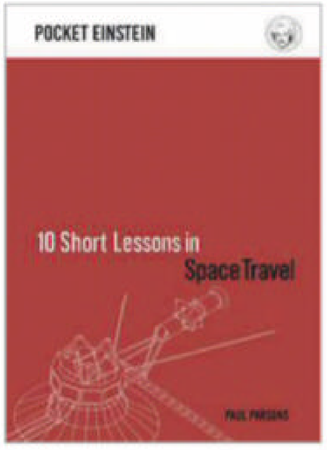
There are some wonderfully poetic metaphors, my favourite being referring to a black hole's event horizon as "a wall between two futures". The narrative lends itself nicely to visualising flying through planetary nebulae, speeding past supernovae or zipping past quasars.

It doesn't shy away from detail (though there's not really any maths) and the final section on "speculative threats" (including cosmic strings and wormholes) is not for the faint-hearted. But then again, I guess you've got to be fairly serious to be considering doing something so dangerous. ★★★★☆

***Dr Chris North** is Odgen science lecturer and STFC public engagement fellow at Cardiff University*

10 Short Lessons in Space Travel

Paul Parsons
Michael O'Mara
£9.99 ● HB



Science writer Paul Parsons' *10 Short Lessons* run the gamut from humanity's earliest desire to explore the cosmos to the realised dreams of today and the untold promise of tomorrow. His down-to-earth witty style is suitably tuned for novice or die-hard space enthusiast alike.

10 Short Lessons in Space Travel traces early ideas of what lay beyond the sky, then delves into our astonishing advances in aviation and rocketry, through times of war and peace, as we took our first footsteps into the Universe in less than a century.

Parsons guides us adroitly through the technical minutiae of his subject matter, condensing complex mathematical equations and theories into easy-to-understand bite-sized parcels. Handy little box-outs pepper the text, offering potted biographies of key figures – from Johannes Kepler to Konstantin Tsiolkovsky and Yuri Gagarin to Arthur C Clarke – as well as snapshots of future missions, including the James Webb Space Telescope, the Lunar Gateway and exotic space elevators.

The book tells of our successes and shortfalls in space, with inspiring quotes drawn from such luminaries as Carl Sagan, Martin Rees and International Space Station astronaut Scott Kelly, who remind us that the voyage to Mars and beyond threatens not only enormous expense and technological difficulty, but also the loss of human lives. And yet Parsons, writing at the start of a decade that promises to finally return humans to the Moon, ends on an upbeat note of optimism. "We truly are the lucky ones," he tells us, "to have a ringside seat for what promises to be the greatest show on Earth." ★★★★☆

***Ben Evans** is the author of several books on human spaceflight and is a science and astronomy writer*

Ezzy Pearson rounds up the latest astronomical accessories

GEAR

1 Baader MaxBright II binoviewer 1.25-inch

Price £390 • **Supplier** Harrison Telescopes
www.harrisontelescopes.co.uk

ADVANCED Make the switch to stereo vision with this binoviewer, which splits the light to let you look through your scope with both eyes. The non-slip finish and ergonomically designed knobs are specifically designed for easy use after dark. Eyepieces not included.

2 RS Pro silia gel dessicator, 50g

Price £14.42 • **Supplier** RS
https://uk.rs-online.com

Damp can ruin a telescope, so use this silica gel desiccator to keep your storage space free of moisture. When the blue indicator turns pink, reactivate the gel by cooking it in the oven.

3 Personalised celestial print scarf

Price £18 • **Supplier** Not On The High Street
www.notonthehighstreet.com

This beautiful scarf is decorated with gold stars and comets. Add a personalised name or initials at the bottom to make a great gift for the space lover in your life.

4 Wooden Solar System Orrery kit

Price £63.72 • **Supplier** Induku Designs
https://indukudesign.com

Assemble your own orrery, depicting the motions of the Moon and Earth around the Sun with this kit. The pieces are laser cut from Baltic Birch plywood and assembly instructions are included.

5 Bresser universal smartphone holder deluxe

Price £13 • **Supplier** Telescope House
www.telescopehouse.com

With suction cups to keep your phone securely in place and the ability to adjust its height, this universal holder allows you to perfectly position your smartphone to take the best photos.

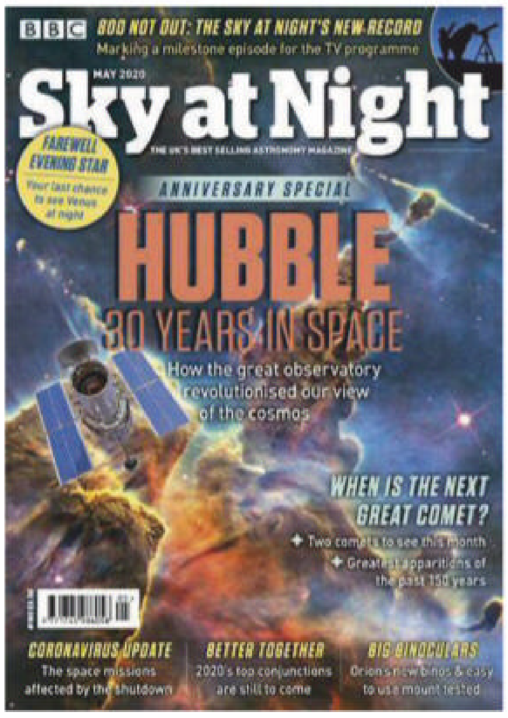
6 Farpoint handle for 3-inch rails

Price £55 • **Supplier** 365 Astronomy
www.365astronomy.com

Carry your telescope and mount with ease, using this simple-to-attach handle that clamps onto a 3-inch dovetail rail. Available with both L- and D-shaped hand holds, the high-quality black anodised clamp will make it easier to transport your kit.

EXCEPTIONAL, RISK-FREE OFFER

DON'T MISS AN ISSUE! FREE DELIVERY TO YOUR HOME



We want to make it as easy as possible for our readers to get their copy of *BBC Sky at Night Magazine* at this difficult time, so we have devised a unique offer for you that we hope will help.

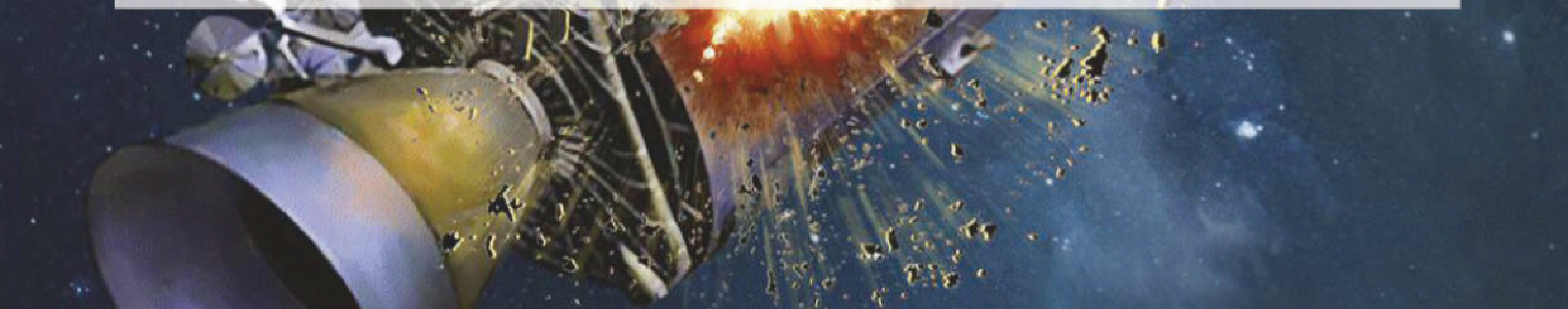
For the next 3 months, we will deliver your copy of *BBC Sky at Night Magazine* direct to your door, for only £14.03 – a saving of 15% on the usual shop price and with no delivery charge*. This offer is risk-free and doesn't require starting a Direct Debit. It simply requires a one-off payment, and if you decide that you do want to cancel before the 3rd issue, we will refund you for any remaining issues**. It's a simple, no-strings way to make sure you get your copy if you are unable to get to the shops. Just order on the link below or call our hotline.

We also regularly run longer term subscription offers, which are only available by Direct Debit. If this suits you better, you will find an offer on pages 24-25 with our current Direct Debit offer on it.

TO RECEIVE 3 ISSUES OF *BBC SKY AT NIGHT MAGAZINE* TO YOUR HOME:

Order online: www.buysubscriptions.com/SKspring3

Or call us on 03330 162 119† and quote code SPR3MPG, *BBC Sky at Night Magazine*



Terms and conditions: *Pay just £14.03 for 3 issues (saving 15% on the shop price). Offer ends 30 June 2020 and is open to UK delivery addresses only. Overseas rates are available. **You may cancel at any time and receive a full refund on any outstanding issues. †UK calls will cost the same as other standard fixed line numbers (starting 01 or 02) and are included as part of any inclusive or free minutes allowances (if offered by your phone tariff). Outside of free call packages, call charges from mobile phones will cost between 3p and 55p per minute. Lines are open Mon to Fri 8am-6pm and Sat 9am-1pm.

Shaoni Bhattacharya interviews Simona Giacintucci

Q&A WITH A RADIO ASTRONOMER

Millions of years ago the biggest explosion in the known Universe ripped through the Ophiuchus galaxy cluster. It's discovery challenges our view of such clusters

▲ **Explosive issue: the study into the Ophiuchus galaxy cluster, by Dr Simona Giacintucci (above) and her co-authors, has made headlines worldwide**

Why were you and your team drawn to study the Ophiuchus galaxy cluster?
We decided to look at the Ophiuchus galaxy cluster, following a paper published in 2016 by Norbert Werner et al, which reported a mysterious, sharp-edged curve in the X-ray image of the cluster taken using NASA's Chandra X-ray Observatory. The feature was in the hot intergalactic gas that fills the galaxy cluster, where the density of the gas dropped abruptly.

That paper briefly considered that this edge might be the wall of a giant bubble blown by a jet from the supermassive black hole in the galaxy cluster's centre. However, when they estimated how much energy would be required to blow such a huge bubble, they thought it was too large to be believable. We wanted to investigate this further.

What did your investigations find?
We discovered that a large extended source of radio waves is located right next to the curved edge. This radio emission comes from fast particles within the bubble, which we believe originated in the central supermassive black hole and were transported away by a jet. The jet drilled through the intergalactic gas and, at some distance from the black hole, blew a huge bubble in the gas, expending a vast amount of energy and filling it with radio-emitting particles.

This tell-tale radio emission confirms a hypothesis previously considered implausible; that we are seeing a remnant of a giant eruption from the black hole. If the hole wasn't filled by a radio emission, it could have been some other feature related to motions of the intergalactic gas.

What did you do in the study?
The patch of the sky containing Ophiuchus has been surveyed by a powerful Australian radio telescope, the Murchison Widefield Array (MWA). We overlaid the MWA image onto the X-ray images of Ophiuchus and found a striking extended radio source right next to the X-ray edge. We then looked at data from the Giant Metrewave Radio Telescope Observatory in India, which creates sharper images. It showed very clearly that the extended radio source fits the X-ray edge like a hand in a glove.

SIMONA GIACINTUCCI

Dr Simona Giacintucci is an astrophysicist and a civilian radio astronomer at the US Naval Research Laboratory in Washington DC

How powerful was this blast and how long ago did it happen?
The energy released is about a billion times the energy of a powerful supernova explosion. The blast created a huge cavity in the intergalactic gas. The diameter of this bubble is 1.5 million lightyears – it would fit 15 Milky Way galaxies in a row.

The bubble is only seen at low radio frequencies, implying the outburst happened long ago, probably a few hundred million years as the super-energetic particles lose energy after they're ejected by the black hole. Their radio emission started fading at high frequencies first, but remained visible at low frequencies for some time. It looks like the black hole has no strong activity at present and all that remains from that enormous outburst is this giant radio fossil filled with aged particles.

What do you think caused this explosion?
The black hole accretes the surrounding matter, which spirals in and forms a very hot disc. Just before it's swallowed by the black hole, some of the matter from the disc is redirected away from the black hole as jets that travel almost at the speed of light. Occasionally, something big falls onto the black hole – like a big cloud of the intergalactic gas, or even a galaxy – and this causes a huge spike in the jet power. We think this is what happened in Ophiuchus.

What are the wider implications of your study?
This discovery challenges our understanding of galaxy clusters. We used to think clusters are so big and massive that they are governed only by gravity. The enormous fossil of an explosion we've found is much bigger than anything we've expected – not insignificant for the cluster's overall energy output. If such 'dinosaurs' turn up in other clusters then we'll have to rethink a lot of things about the physics of galaxy clusters and how they are used in studies of the Universe.


Telescope House
Telescope Specialists Since 1785
Web: www.telescopehouse.com
Email: sales@telescopehouse.com
Tel: 01342 837098
Sign Up
16MP - £842
1.7MP - £1256
7.1MP - £2099
Explore Scientific iEXOS-100 Wifi Mount £349
Explore Scientifc 127mm FCD100 Carbon Fibre Apo - £2287
EXPLORE SCIENTIFIC
Introducing the three new Explore Scientific Deep Sky Cameras - all simple to use One Shot Colour systems featuring 1.7, 7.1 and 16 Megapixel Sensors. These cameras all feature set-point cooling and come with control software and heavy duty storage & carry cases.
165mm & 152mm + Losmandy G11 PMC8 Mount Megadeals
Telescope House are pleased to bring you these two unique deals buy the extraordinary Explore Scientific 165mm or 152mm Apo Triplets together with the advanced Explore Scientific Losmandy G11 PMC8 Wireless Control Mount and make massive savings.
Explore Scientifc 99% Reflectivity Diagonal - £142
PMC EIGHT
PRECISION MOTION CONTROLLER
Explore Scientifc Maksutov Newtonian - £892
TeleVue
Browse the complete TeleVue eyepiece range on our website
Get organised with the Explore Scientifc Eyepiece & Accessory Bag- £25
NEW!
Introducing the Explore Scientifc 52-Degree Eyepiece Waterproof LER range From £59.99
NEW!
Bresser Astrophoto Tracking Mount From £265
The Bresser Astrophoto Tracking Mount is designed to be used with DSLRs and small telescopes for long duration astrophotography, providing a tracking platform to counteract the Earth's rotation and create wonderful wide field shots of the skies above us.
Available in head only and wedge tripod configurations.
Explore Scientific Sun Catcher Solar Filters From £18
HOT PRODUCT 2015 SKY
Lunt LS50 - From £1183
Excellent pressure-tuned portable Solar Scope
Explore Scientific Solarix Solar Film Filter £18
Lunt LS60 - From £1880
Excellent Value 100% Safe Solar Film. Ideal for DIY!
Lunt LS80/B1800 - £5214
Find the full range of ZWO Cameras at Telescope House From £151
ZWO
Bresser Full HD USB Camera/ Eyepiece £50
Lunt LS100/ B1200 - £6478
ZWO ASIAIR Pro Wireless Scope control, Autoguiding & more. Arriving soon!
Website: www.telescopehouse.com
Email: sales@telescopehouse.com | For sales and advice call: 01342 837098
All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

As Jupiter and Saturn both reach opposition this month, we follow the trail of Comet 2P/Encke

When to use this chart

1 July at 24:00 AEDT (13:00 UT)
15 July at 23:00 AEDT (12:00 UT)
31 July at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

JULY HIGHLIGHTS

Comet 2P/Encke is famous for being a comet with one of the shortest periods, only 3.3 years. Since passing through perihelion in late June, 'Encke' has moved into the evening sky. The comet opens July in Cancer at its maximum brightness (possibly 7th magnitude), setting around the end of astronomical twilight. As it moves away from the Sun it gains altitude, passing through Hydra, Sextans and Crater before closing July near the trapezium of Corvus.

STARS AND CONSTELLATIONS

The ancient constellation of Hercules is marked by a distinctive asterism of six stars sitting close to the evening northern horizon. This Greek god is typically depicted as kneeling on his right leg with his left arm stretched out towards Lyra. Today, this hand is empty, however some early star maps showed him gripping Cerberus. This now obsolete constellation recognised the 12th task of Hercules where he fought the three-headed monster (shown as a dog or snake) that guarded the underworld.

THE PLANETS

This month is planet-observer heaven, with both Jupiter and Saturn at opposition, rising around sunset and visible for the whole night. Both reside in Sagittarius, with Jupiter following the Teapot and Saturn close behind. Although Neptune and Mars rise in the evening they are best observed in the morning. Brilliant Venus is high in the predawn eastern sky, passing near Aldebaran on the 11th. Mercury returns to the dawn glow but remains low, reaching maximum altitude on the 23rd.

DEEP-SKY OBJECTS

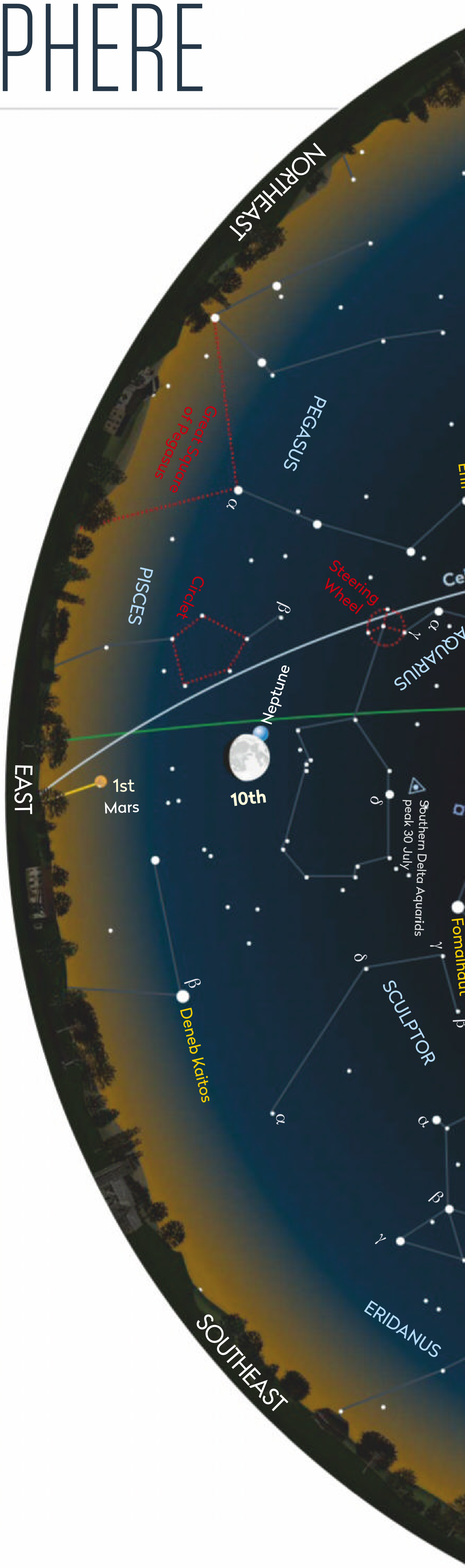
This month we visit the constellation of Libra. Starting at naked-eye star Sigma Librae, move 4.1° NNW to find the brilliant double star HN 28 (RA 14h 57.4m, dec. –21° 24'). The main components are mag. +5.8 and +8.2, separated by 24". Their colours offer an impressive contrast – orangy yellow and red respectively.

Return to 'Sigma', jump 3.5° ENE to discover an impressive close pair of galaxies, NGC 5898 (RA 15h 18.2m, dec. -24° 06') and NGC 5903, 0.1° to its west. Although both are 11th magnitude ellipticals and of similar size there are some interesting differences. NGC 5898 shows a round, evenly illuminated 1' halo with very little brightening towards the centre. In contrast NGC 6903 has a more elongated, diffuse 0.8' x 1.3' halo with an obvious star-like nucleus.

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE




NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
DRACO
HERCULES
M92
Keystone
M13
CORONA BOREALIS
BOÖTES
Arcturus
Kite
LYRA
Vega
Summer Triangle
Deneb
NGC 7000
CYGNUS
M29
Northern Cross
M57
Albireo
Veil Nebula
VULPECULA
M27
M71
SAGITTA
Collinder 399
Rasalgethi
Rasalhague
DELPHINUS
EQUULEUS
M15
AQUILA
Altair
IC 4665
OPHIUCHUS
SERPENS CAPUT
SERPENS CAUDA
M5
Celestial Equator
M2
Alpha Capricornids peak 30 July
NGC 7009
M14
M12
M10
M11
SCUTUM
Coffin
M17
M25
4th
M107
M9
29th
VIRGO
LIBRA
Ecliptic
Saturn
Jupiter
M75
M22
M8
7th
1st
26th
M19
M62
M6
M7
Antares
M55
Teapot
HN 28
NGC 5898
NGC 5903
Spica
M30
CAPRICORNUS
MICROSCOPIUM
SAGITTARIUS
CORONA AUSTRALIS
SCORPIUS
NORMA
LUPUS
Piscis Austrinids peak 28 July
PISCIS AUSTRINUS
GRUS
INDUS
ARA
PAVO
TRIANGULUM AUSTRALE
CORVUS
M68
HYDRA
CENTAURUS
ω Cen
Rigel Kentaurus
31st
Comet 2P/Encke
CIRCINUS
TUCANA
PHOENIX
OCTANS
APUS
NGC 4755
Jewel Box
Coalsack
47 Tuc
SMC
Achernar
South Celestial Pole
CHAMAELEON
MUSCA
CRUX
IC 2944
Collinder 240
HYDRUS
Southern Pleiades
NGC 3532
MENSA
CARINA
Eta Carina Neb
Miaplacidus
RETICULUM
NGC 2070
LMC
VOLANS
VELA
False Cross
DORADO
PICTOR